Developing an integrated implementation plan for control and elimination of NTDs: Nationwide mapping surveys for lymphatic filariasis, schistosomiasis and soil-transmitted helminthiasis in Zambia

A thesis submitted per the requirements of the University of Liverpool for the degree of Doctor of Philosophy

by

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Declaration

I hereby certify that this dissertation constitutes my product, that where the language of others is set forth, quotation marks so indicate, and that appropriate credit is given where I have used the language, ideas, expressions or writings of another.

I declare that the dissertation describes original work that has not previously been presented for the award of any other degree of any institution.

Signed,

Mutale Nsakashalo

Abstract

Zambia like most countries in Southern Africa is non-endemic for onchocerciasis. However, this also means that unlike many African countries that are experienced in community-directed delivery of medicines for helminthiasis, Zambia is relatively naive to preventive chemotherapy and associated delivery strategies, such as community-based mass drug administration (MDA). The present integrated approach the WHO is promoting for control of neglected tropical diseases (NTDs), targets conditions that are amenable to preventive chemotherapy using ivermectin (IVM) or diethylcarbamazine (DEC) with albendazole (ALB) for lymphatic filariasis (LF), ivermectin for onchocerciasis, praziquantel (PZQ) for schistosomiasis (SCH) and ALB or mebendazole (MBD) for soil-transmitted helminthiasis (STH). Recent advancements and external assistance to the country has supported the initiation of these programmes. In areas free of onchocerciasis, the WHO guidelines for helminth control advise intervention through community-directed MDA strategies using DEC and ALB for LF. The first plan recommended for SCH, and STHs control is co-administration of PZQ and ALB through targeted large-scale distribution using a school-based treatment delivery system targeting all school-age children. Zambia is a developing country which, following several sporadic studies, has produced evidence of the presence LF, SCH and STH which are widespread and amenable to MDA and could be controlled on the same platform. Past and current information outlines that active transmission of these NTDs is ongoing and needs urgent intervention to control morbidity. This PhD study, in six chapters addressing specific topics, will be in line with the WHO Global Programmes for the control of NTDs using an integrated strategy including capacity development for mapping and monitoring and evaluation as central to this project. The aim is to review the national policies on NTDs and construct solutions to address the main gaps and challenges as the country plan to scale up integrated interventions for control and elimination of specific NTDs based on the study findings. with evidence from nationwide mapping surveys for LF, SCH and STH in Zambia. A significant decrease in LF prevalence from the years 2003–2005 (11.5% CI95 6.6; 16.4) to 2012–2014 (0.6% CI95 0.03; 1.1); a significant scale-up of ITNs across the country from 0.2% (CI95 0.0; 0.3) to 76.1% (CI95 71.4; 80.7), respectively. ITN coverage was a better predictor of LF prevalence than year alone with a significant Spearman's correlation of -.462 at the 0.01 level (2-tailed), R^2= 0.1878 (year alone)

and 0.2837 (year and ITN coverage). 39,904 children tested for SCH and STH in 1349 schools. The overall prevalence for schistosomiasis is 16.6 % while STH was 22.0 %. The highest prevalence reported in Lusaka (65.3 %) and Northwestern (41.9 %) for SCH and STH respectively. Most participants were aged 10-12 years and also had the highest prevalence of *S. haematobium* followed by 13-15 years who had the highest prevalence of hookworm. Pearson Chi-Square test on age group indicated statistically significant difference at 4 degrees of freedom X^2=372.766 (*S. mansoni*), X^2=353.108, (hookworm) and X^2=94.965 *(A. lumbricoides)* at $p<0.0005$. Univariate and multivariate analysis revealed correlation on the independent environmental and climatic predictors with SCH and STH prevalence. The general information collected from this research will be used for policy development and provide direction for the National Neglected Tropical Diseases programme in line with the National Health Strategic Plan 2017- 2021 that has a focus on primary health care and community health approaches. Currently, there are no nationwide MDA campaigns for SCH and STH being implemented, but LF MDAs have been going on since 2012/13 and have already reached the fifth round in one province. Therefore, the NTD policy or strategic plan should be comprehensively revised to highlight the national NTD goals, strategic objectives, and key performance indicators for the next five years and beyond.

The putative synergy of LF prevalence with vector control has provided evidence that helped to put Zambia on track to meet national and global goals of LF elimination by 2020. The distribution of SCH and STH is widespread with varying risks of transmission. The maps produced will provide the evidence on the areas targeted for interventions in Zambia.

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I hope that the work undertaken will contribute to improving the planning and implementations of interventions concerning integrated primary health care as the focus of the thesis. It is anticipated that the Ministry of Health and other key stakeholders will utilise the findings and prevent further transmission in the affected communities.

Dedication

I dedicate this work to my late father Edward Gabriel Chomba Nsakashalo, who died on 6 April 2003, for sending me to school, instilling in me confidence and making me believe that I could achieve anything I wanted if I remained focused and believed in myself.

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List of Key Abbreviations

AFRO	African Regional Office
ALB	Albendazole
Ag	Antigenaemia
ATM	Annual Temperature Mean
CDC	Centres for Disease Control
CDD	Community Drug Distributors
CDI	Community Drug Interventions
CDTI	Community Drug Treatment with Ivermectin
CFA	Circulating Filarial Antigen
CI	Confidence Intervals
DDT	Dichlorodiphenyltrichloroethane
DEC	Diethylcarbamazine
DHO	District Health Office
GAELF	Global Alliance to Eliminate Lymphatic filariasis
GPELF	Global Program to Eliminate Lymphatic filariasis
GRZ	Government of the Republic of Zambia
ICT	Immunochromatographic Test
IEC	Information, Education, Communication
IRS	Indoor Residual Spraying
ITN	Insecticide Treated Nets
LF	Lymphatic Filariasis
LLIN	Long Lasting Insecticide Nets
MBD	Mebendazole
MDA	Mass Drug Administration
mf	Microfilariae
MoH	Ministry of Health
MCDMCH	Ministry of Community Development Mother and Child Health
NGO	Non-Government Organization
NTD	Neglected Tropical Diseases
OR	Odds Ratio
PHO	Provincial Health Office
PPP	Public Private Partnerships
PZQ	Praziquantel
SCH	Schistosomiasis
SCI	Schistosomiasis Control Initiative
STH	Soil-transmitted Helminthiasis
TAS	Transmission Assessment Survey
UHC	Universal Health Coverage
UNGA	United Nations General Assembly

UNICEF	United Nations Children's Fund
UTC	Uniting to Combat
Wb	*Wuchereria bancrofti*
WHA	World Health Assembly
WHO	World Health Organization
ZBCP	Zambia Bilharzia Control Programme

Chapter 1 General overview

1.1 Introduction

To date Zambia has had no sustainable neglected tropical disease control programme due to inadequate information on the extent of the disease distribution and burden, inadequate expertise and funds. Most interventions in the past have been fragmented with no clear coordinated roadmap. Zambia is a landlocked country in Southern Africa neighbouring Democratic Republic of Congo in the north, Tanzania to the north-east, Malawi on its eastern border, Mozambique, Zimbabwe, Botswana and Namibia to the south and Angola on its western border as shown in Figure 1.1. Zambia was called Northern Rhodesia, before its independence in 1964. It has a tropical climate and consists mostly of high plateau, with some hills and mountains, dissected by river valleys. At 752,614 km2 (290,586 sq mi) it is the 39th-largest country in the world and lies mostly between latitudes 8° and 18°S, and longitudes 22° and 34°E (https://www.worldatlas.com/webimage/countrys/africa/zambia/zmlinks.htm#page .

Zambia is sparsely populated at 16 million people in 2019 with a growth rate of 2.89% and has over 70 ethnic groups. Millions of Zambians are said to live below the World Bank poverty threshold of $1 a day. The 0-14-year-old category takes up 46% of the population, 20% by 15-25-year-old, 28% by 25-54 year olds and only 5.3% for those 55 years and above. This clearly shows that Zambia has a relatively young population. Only 61% of the population has clean drinking water source (87% of the urban population and 46% of the rural population). Sanitary facilities are still very low with a total of 52% of the population (57% urban and 43% rural) with improved sanitary facilities. The total primary school enrolment ratio both sex has increased from 77% in 1998 to 97% in 2010 (Office, 2012).

Figure 1-1 location of Zambia on the African continent

Map showing the location of Zambia on the African continent. It is a landlocked country in the Southern part of Africa sharing its boundary with 8 countries (Hobson, 2020)

Neglected tropical diseases (NTDs) are a group of 20 bacterial, viral and parasitic infections that are strongly associated with poverty. The seven most common NTDs include, soil-transmitted helminthiasis (STHs), lymphatic filariasis (LF), schistosomiasis (SCH), onchocerciasis, trachoma, leishmaniasis and trypanosomiasis. According to the World Health Organisation the diseases are all medically different yet are all strongly related to poverty and very common in tropical and subtropical areas affecting mostly the poor and marginalized communities (Engels and Zhou, 2020). In 1999, WHO launched the Global Programme to Eliminate Lymphatic filariasis (GPELF) with the goal to interrupt disease transmission by 2020 (Molyneux and Zagaria, 2002). The resolution to control and

eliminate schistosomiasis was passed during the 54th World Health Assembly (World Health Organization, 2001). More recently, an increased influx in funds for NTD control programmes has led to intensified efforts to control and where possible eliminate NTDs (Hotez et al., 2017). Success in eradicating Guinea worm from the majority of endemic countries has also increased interest in tackling other NTDs which was previously endemic in more than 20 countries but now only four countries are reporting human infections (South Sudan, Chad, Ethiopia and Mali, and animal infections (Ethiopia and Chad) (Rawla and Jan, 2020). Most of the NTDs can be addressed on the same platform in an integrated manner. WHO has developed tools to guide countries on integrated control of multiple NTDs requesting countries to align their vertical control strategies for individual diseases to form a single NTD integrated master plan (Engels and Zhou, 2020) which will be more cost effective and sustainable.

In Zambia, the diseases are common and affect people living in remote areas and the peri-urban areas with poor sanitary conditions (Mwase et al., 2014). Morbidity and mortality due to NTDs has been reported in some hospitals especially in children with schistosomiasis complications in the North-western part of the country (Kalinda et al., 2018). Despite the extent of morbidity and reported children with hepatosplenomegaly due to schistosomiasis treated in a paediatric unit of Lusaka (the case was referred from Northern Province) portal fibrosis related to *S. mansoni* in western province (Kalinda et al., 2018) and elephantiasis found during the mapping of lymphatic filariasis in Zambia (Mwase et al., 2014), NTDs were classified as of low importance on national and international health agendas in comparison to HIV/AIDs, tuberculosis or malaria.

Zambia is free of onchocerciasis however this also means that unlike many African countries that are experienced in community-directed delivery by the African Programme for Onchocerciasis Control (APOC) (Gebrezgabiher et al., 2019), they remained naive to preventive chemotherapy (PC) delivery strategies, such as mass drug administration (MDA) using CDTi. The present integrated strategy WHO is promoting for control of NTDs, targets diseases that are amenable to the PC using praziquantel for schistosomiasis, albendazole or mebendazole for soil-transmitted helminthiasis, ivermectin for onchocerciasis and a combination of ivermectin or

diethylcarbamazine with albendazole for LF (Gabrielli et al., 2011). With the recent advancements and external assistance to Zambia, the country is now in a position to initiate the NTD integrated programmes which at the start of the project were non-existent. In areas free of onchocerciasis, the WHO guidelines for helminth control advise delivery through community-directed mass drug administration (MDA) strategies using DEC and albendazole for LF (Gabrielli et al., 2011). The main strategy advised for schistosomiasis and STHs control is praziquantel and albendazole through targeted large-scale distribution using a school-based delivery system targeting all school-age children (Gabrielli et al., 2011).

The aim of this study is to develop an integrated implementation plan for control and elimination of NTDs with a focus on nationwide mapping surveys for LF, schistosomiasis and soil-transmitted helminthiasis in Zambia.

1.2 Study Rational

At the start of the research, Zambia had no sustainable mass drug administration programme due to inadequate of information on disease burden, distribution and inadequate support. With external funds, Zambia is now in a position to develop and maintain PC programme for integrated neglected tropical diseases (NTD) control, and where possible elimination. As the country is free of onchocerciasis, they are naïve to the community-directed treatment with ivermectin (CDTI) strategy through health volunteers. This presents a rare opportunity to use DEC in an African country which continues to kill the microfilariae for a longer time than ivermectin (King et al., 2018) and has been used more commonly in Asia and not Africa (Fang and Zhang, 2019, Kapa and Mohamed, 2020, Ojha et al., 2017, Specht et al., 2019, Yajima and Ichimori, 2020). It also provides an opportunity to develop a comprehensive NTD delivery strategy with the aid of community health volunteers.The study will observe the nationwide mapping surveys for LF, schistosomiasis and soil-transmitted helminthiasis and develop an integrated implementation plan for control and elimination of NTDs in Zambia.

1.2.1 Aim and specific objectives

The aim of this study is to assess the distribution of LF, SCH and STH, measure the associated risk factors and determine the treatment requirement for an integrated NTD Elimination Programme.

The specific objectives to achieve this aim are as follows and are presented as individual chapters.

1. To examine the LF transmission dynamics and potential impact of vector control
2. To assess the distribution of schistosomiasis and soil transmitted helminthiasis in Zambia
3. To conduct a policy analysis for the NTD programme in Zambia
4. To develop recommendations, prospects for 2030 and future research plan for the NTD programme in Zambia.

1.3 Links to national and international priorities

Zambia is a developing country which, following a number of sporadic studies (Simoonga et al., 2009, Clements, 2005, Siziya and Mushanga, 1996) has produced evidence of the presence of schistosomiasis, soil transmitted helminthiasis, lymphatic filariasis, trachoma, Human African Trypanosomiasis, cysticercosis and leprosy of which five are widespread and amenable to MDA and could be controlled on the same platform. Past and current information outlines that active transmission of these neglected tropical diseases is ongoing and needs urgent intervention to correct the situation. This study will be in line with the WHO Global Roadmap for NTDs (World Health Organization, 2012a) using an integrated strategy and the Regional Plan of Action for NTD 2014-2020 (World Health Organization, 2013d). The purpose for this PhD research, therefore, is to assess the demographic, epidemiological, environmental and geographical factors that contribute to persistence of transmission of three PC NTDs. It will also review the influencers of the NTD policy in the health sector. NTDs are prioritised in the National Development Plan and National Health Strategic Plan 2017-2021 (Ministry of Health, 2016).

Coordinated, integrated mapping and integrated data management are high on the international priority list for research on NTDs. Capacity development for mapping and monitoring and evaluation will be central to this project. Assessment of the dynamics and determinants of persistent transmission will be key. The information that will be collected will be used for policy development to provide the direction for the National programme.

An extensive literature search in Google and PubMed in 2010 and repeated in 2018 was conducted using key words: lymphatic filariasis, elephantiasis, LF, *Wuchereria bancrofti*, Zambia, schistosomiasis (*Schistosoma haematobium, Schistosoma mansoni*), soil-transmitted helminths (*Ascaris lumbricoides*, hookworm, *Trichuris trichiura*), neglected tropical diseases, NTDs, bilharzia, praziquantel, DEC, diethylcarbamazine, IVM, ivermectin, mass drug administration, integrated health plan. It was found that no research on integrated control of NTDs has been done in Zambia (Personal communications with Ministry of Health NTD officers, Medical Research Ethics and the Director Tropical Diseases Research Centre in Zambia).

1.4 Layout of the thesis

Chapter one provides a general overview of the thesis, a brief Zambian situation with regards to preventive chemotherapy NTDs with a focus on LF, SCH and STH. This is followed by the overall aim and objectives, the link of my study to national and international priorities and the structure of the rest of the thesis.

Chapter two provides a review of the literature on the three NTDs included in this thesis. It provides the general information, history of the parasite, vectors, diagnostics, clinical manifestations and the global initiatives and targets in the prevention, control and elimination of the lymphatic filariasis, schistosomiasis and soil transmitted helminthiasis.

Chapter three maps the decline in lymphatic filariasis prevalence and the potential impact of vector control, examined the changing of LF in Zambia by using the endemicity or prevalence maps, sentinel site baseline surveys before the scale up of MDA and examine the potential additive impact of vector control used for malaria which targets the same mosquitoes. There is significant evidence to conclude a negative linear relationship between vector control (ITN coverage) and LF prevalence and reject the null hypothesis (there is insufficient evidence to conclude). The assumption that the intensified vector control in the malaria programme reduced the prevalence of LF in Zambia even before the commencement of mass drug administration hence accepting the research hypothesis that vector control alone can reduce the prevalence of lymphatic filariasis.

Chapter four examines the distribution of schistosomiasis and soil transmitted helminthiasis in Zambia by conducting school surveys across the country, demographics, spatial analysis of the hotspots and the associations between temperature, altitude, precipitation and soil types and the five species under study in this chapter. It also provides an insight on the projected treatments for the next five years. The chapter tests the Ho that previous predictive maps produced for Zambia provides accurate information for programme interventions. It also tests the Ho that the strength of association between the different species for SCH and STH and the environmental and climatic predictors (precipitation, temperature, soil types and altitude) is the same in Zambia. The Chapter also tests the research hypothesis that the four species endemic in Zambia have significant spatial distribution. The chapter reaffirms the statistically no significant difference among observed frequencies and expected frequencies when the two test for *S. haematobium* are used (urine filtration and dipstick for heamturia).

Chapter five is the policy analysis of the NTD programme in Zambia. It makes a comparison between WHO the government or national NTD programme has implemented and the WHO NTD Roadmap for 2012-2020. This Chapter is testing the Ho that there are no internal and external influencers in the development of an NTD policy. The chapter tries to make an explicit link between implementation of the NTD programme intervention to the sustainable development goals and universal health coverage. How does the global community including the SDGs and UHC influence the focus of the programme to achieve them? It also identifies other influencers in policy development in the country, the policy gaps and solutions. The chapter concludes that the national NTD programme should come up with approaches that will lead to the control and elimination with the effective implementation of the five main strategies outlined in the NTD Roadmap, through multisector - multistakeholder approach, and other initiatives.

Chapter six provides an overview of all preceding chapters with a summary highlighting the key findings. It looks at why expand campaigns for the LF, STH and SCH in Zambia now, highlights some of the innovations, integration with other community-based health care service deliveries including the possibility of utilising existing structures for WASH projects, immunisation programmes, social cash or

social welfare benefit scheme, social media and any planned decentralisation plans. It also describes the future possible research areas and programmatic recommendations on how to scale-up the current efforts based on the study findings.

Chapter 2 Literature review on lymphatic filariasis, schistosomiasis and soil- transmitted helminthiasis

2.1 Introduction

Neglected Tropical Diseases (NTDs) are a group of chronic, disfiguring and disabling conditions affecting the poor and marginalised populations in the developing world. 20 NTDs which include bacterial, parasitic, mycoses, ectoparasites, or viral infections have been prioritised and include protozoan infections (leishmaniasis, trypanosomiasis - Human African and American trypanosomiasis - Chagas disease); bacterial infections (*Trachoma*, leprosy, yaws, and buruli ulcer); and helminthic infections (STH i.e. hookworms, *Ascaris, Trichuris);* Lymphatic filariasis, onchocerciasis, dracunculiasis, cysticercosis, echinococcosis, fascioliasis and schistosomiasis; mycoses (mycetoma, chromoblastomycosis), ectoparasites (scabies) and viral infections (rabies, dengue fever and chikungunya) have been prioritised (Engels and Zhou, 2020). These diseases are all medically different yet are all strongly related to poverty and very common in tropical and subtropical regions (Engels and Zhou, 2020). In most of the communities, families and even individuals are affected by these NTDs. Morbidity and mortality perpetuate poverty significantly by diminishing economic productivity in affected adult populations and intellectual and physical development of a younger generation (Hotez and Herricks, 2015). Because NTDs are more of disablers than killers (Hotez et al., 2014) they were for a very long time of low importance on national and international health agendas in comparison to other communicable diseases such as HIV/AIDs, tuberculosis or malaria (Hotez et al., 2006b) that present more acute requiring immediate treatment, causes mortality faster if not treated and also affect the affluent people.

Globally, women and children who live in unsanitary environments face the biggest threat of NTDs (World Health Organization, 2012a). The good news is that five of these common NTDs have similar strategies on preventive measures with all of them requiring preventive chemotherapy once or twice yearly. They include soil transmitted helminthiasis (ascariasis, trichuriasis, hookworm), lymphatic filariasis,

schistosomiasis, onchocerciasis, and trachoma (Gabrielli et al., 2011). Most of these NTDs are endemic in same intervention implementation units making it easy to integrate interventions as health education, preventive chemotherapy, water, sanitation and hygiene (WASH) and targeted integrated vector control could be performed for more than one NTD at the same time in a particular location (Kabatereine et al., 2011).

Africa contributes an estimated 40% of the disease burden of five PC NTDs such as Trachoma, STH, LF, Onchocerciasis, schistosomiasis, with approximately 406 million people requiring treatment for LF, 114 million for onchocerciasis, 216 million children for SCH and 284 million children for STH (World Health Organization, 2013f). Most of the African countries have at least two of the NTDs that are targeted through PC and 36 countries are endemic for more than 5 PC NTDs as shown in Figure 2.1. With the inadequacies in health systems in most African countries (Gyapong et al., 2010) it has been very difficult to implement interventions to prevent, control and eliminate these NTDs making it difficult to sustain control and elimination programmes. But a lot of support is now coming in from various donors towards the implementation of interventions. In 2012, over 800 million people treated for PC-NTDs globally (World Health Organization, 2015).

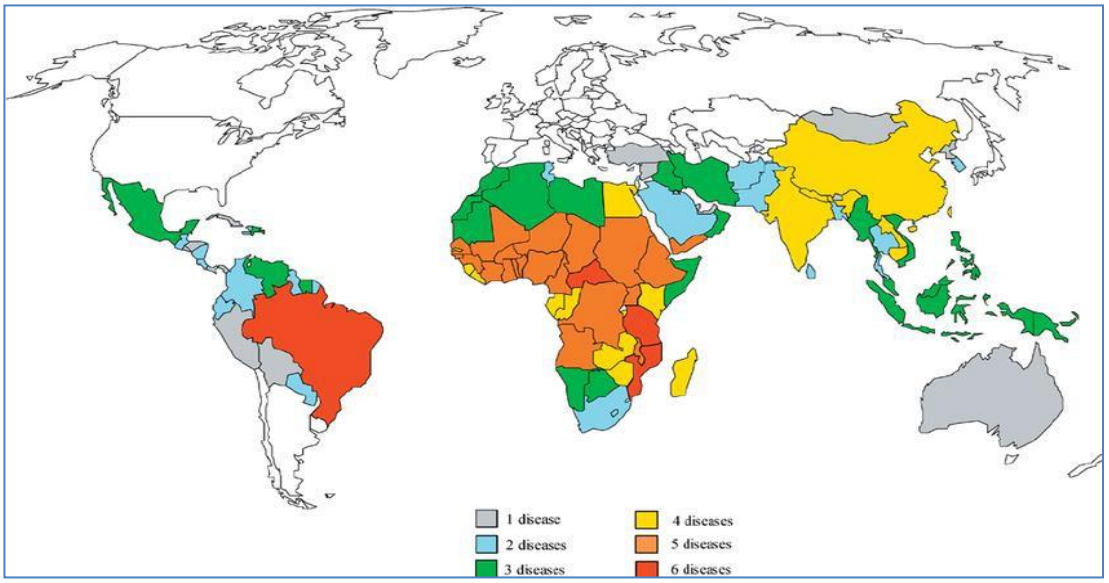


Figure 2-1 Global Distribution of PC NTDs

Source: (Molyneux et al., 2005). The map is showing the global distribution of PC NTDs. Most countries that have more than 4 PC NTDs are in Africa and South America. Zambia is one of the countries with 4 PC NTDs in the map. These NTDs include STH, SCH, LF and Trachoma.

In addition, NTDs, like any other communicable diseases, it can be eliminated and eradicated with improvements in housing, water supply, sanitation, environmental manipulation and health education (World Health Organization, 2017c). WHO has targeted some of these NTDs for elimination, control and others for eradication by the year 2020. To this effect a resolution was passed at the 50th World Health Assembly to eliminate LF by 2020 (World Health Organization, 1997b) which subsequently led to the launch of the Global Programme to Eliminate LF (GPELF) . Four years later, another resolution was passed to tackle SCH and STH (World Health Organization, 2001). This was due to the concern on the number of people reported to have been affected by the two NTDs and the related morbidity.

2.2 Community Directed Ivermectin Treatment (CDTI)

Community Directed Treatment with Ivermectin (CDTI), is a strategy where treatment is executed by the communities in endemic areas, and is being used by a number of countries endemic with onchocerciasis since 1997 (Dadzie et al., 2018). The community directed distributors (CDD's) are trained and selected from the community to administer treatment under minimal supervision. Zambia being Non-onchocerciasis country did not benefit from CDTI for the treatment of LF as only the countries co-endemic with onchocerciasis benefited from the Ivermectin donations. Many communities directed programmes emulated this strategy and it has been recommended for so many community programmes (Amazigo et al., 2006) including the recently introduced mass drug administration against malaria (Development), 2017) to enhance the efforts towards its elimination. This in most cases is being referred to as community directed interventions (CDI). It is an accepted and effective strategy in mass treatment of schistosomiasis and STH infections in resource constrained communities.

2.3 Lymphatic filariasis

2.3.1 General information

Lymphatic filariasis is infection by a thread-like filarial worm of the species *Wuchereria bancrofti*, *Brugia malayi* or *B. timori (World Health Organization, 1984)*. Filarial worms are nematode parasites belonging to the class Secernentia, order Spirurida and superfamily Filarioidea that live in tissues and body cavities of a vertebrate host and intermediate host too. There are two families within the

superfamily Filarioidea namely Filariidea and Onchocercidae and the filarial parasites infecting man belong to the family Onchocercidae. These parasites are transmitted to humans through the bite of an infected mosquito and develop into adult worms in the lymphatic vessels (World Health Organization, 1984) using severe damage and swelling (lymphoedema). Elephantiasis – painful, disfiguring swelling of the legs and genital organs – is a classic sign of late-stage disease (King, 2001, King et al., 2001). Treatment using, DEC, albendazole and ivermectin to prevent continuous transmission by drastically reducing microfilaremia is available(Gabrielli et al., 2011). However, in advanced chronic conditions additional treatment measures are required such as surgery for hydrocele, care of the skin and exercise to increase lymphatic drainage in lymphoedema. Annual treatment of all individuals at risk (individuals living in endemic areas) with recommended anti- filarial medicines such as combination of diethylcarbamazine citrate and albendazole; or ivermectin and albendazole; or the regular use of DEC fortified salt can prevent occurrence of new infection and disease (Nandha and Krishnamoorthy, 2007). Precaution is taken in loasis endemic areas where monotherapy MDA with albendazole for eliminating LF is recommended (Gabrielli et al., 2011). This is to reduce the risk of death and neurological complications from *L. loa* encephalopathy.

2.3.2 The burden of lymphatic filariasis

Progress has been made in mapping the distribution of LF providing a general overview of LF globally. Over 1,403 million people live in countries where preventive treatment for LF is required. Africa and South-East Asia regions harbour 95% of the population living in endemic areas, and 98% of the infected population. Of the total population requiring preventive chemotherapy for LF, 866 million (62%) live in the South-East Asia Region (9 endemic countries) and 464 million (33%) live in the African Region (34 countries) (World Health Organization, 2010). The Region of the Americas, Eastern Mediterranean Region and Western Pacific Region (with 4, 4 and 22 endemic countries, respectively) together account for 5% of global distribution (Organization, 2017) .

Overall prevalence of filariasis cases is 2.0% globally, the disease continues to be of considerable local importance, particularly in India and Sub-Saharan Africa as shown in Figure 2.2. Estimates by age and gender clearly show that, unlike other

helminth infections, filariasis is mainly a disease of the adult and older age-classes and appears to be more prevalent in males (Michael et al., 1996). LF is a major cause of acute and chronic morbidity in 81 countries in Asia-Pacific, Africa and Americas with approximately 1.3 billion living in these tropical and sub-tropical regions being at risk of infection (Bockarie et al., 2009a).

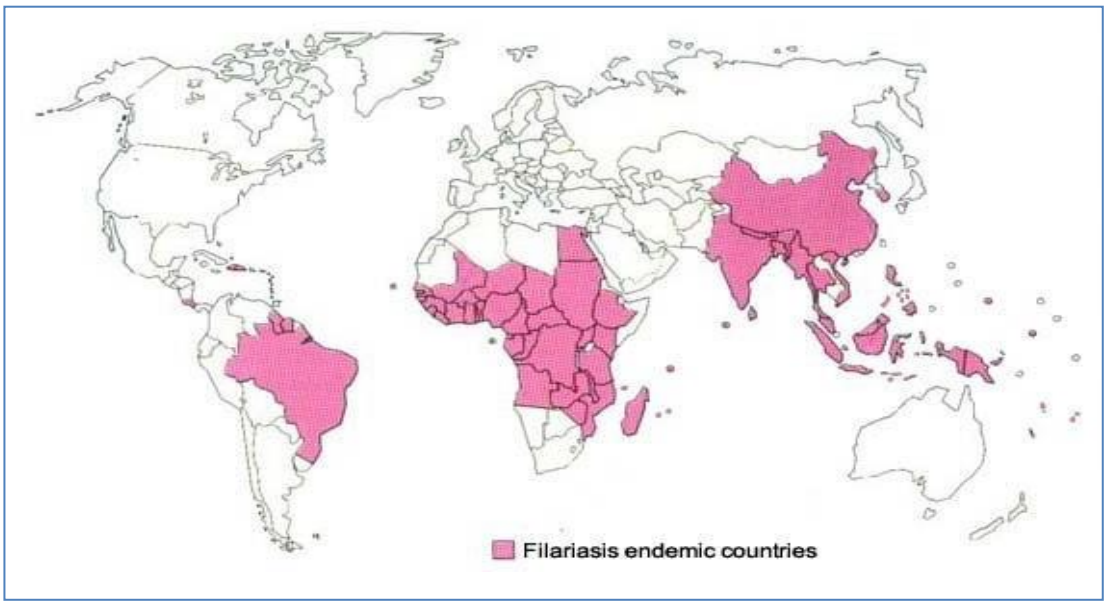


Figure 2-2 Map showing lymphatic filariasis endemic countries globally.

Source: https://hdi.no/project/lymphatic-filariasis/. Sub-Saharan Africa, Asia and South America are endemic for LF.

2.3.3 The parasite, its periodicity and life cycle

Previous studies have documented that more than 90% of LF is caused by *W. bancrofti*, while the remaining 10% is caused by *B. malayi* and *B. timori (World Health Organization, 1984)*. The disease or condition are usually classified according to the final habitat of the adult worms in the lymphatic system or because of an immune response of the human host to microfilariae (Ottesen et al., 1997 resulting into lymph stasis (elephantiasis), lymphangitis, hydroceles, lymphoedema of the affected parts of the body while the immune reactions present as eosinophilia. Therefore, the immune status of an individual has a major role in this.

Of much interest in the epidemiology of LF is the concept of periodicity which is a classical feature. The microfilariae present in large quantities in the

peripheral blood at a specific period in the night of the 24-hour cycle referred to as nocturnal periodicity. In the nocturnally periodic forms of the parasite, the greatest density of microfilaria between 9 o'clock in the night and 2 o'clock in the morning and also most non-existent during the day. This is the reason why microfilaria is transmitted by mosquitoes that bite at night such as the anophelines (Bockarie et al., 2009a). In other periodicities such as the diurnal periodic filariasis the micro filarial density is high during the day while in diurnal sub-periodic filariasis, its higher at night, but microfilariae are still present during the day corresponding to the biting habits of the principal vectors which in this case is the *Aedes* and *Mansonia*(Bockarie et al., 2009a) to ensure transmission. *Wuchereria bancrofti* is the only known aetiologic agent of LF in Zambia (Mwase et al., 2014) and its microfilariae show nocturnal periodicity. However, the peak hours have not been determined, requiring more studies to be conducted around the periodicity and LF in Zambia. In sub-periodic filariasis found in Fiji in the pacific region, significant levels of the microfilariae are found in peripheral blood throughout the 24-hour period with highest levels in the morning and evening (Ichimori and Crump, 2005), but numbers increase at a specific period while in the diurnal sub-periodic type, the concentration of microfilariae in peripheral blood increases in the daytime. The main vector for this type of filariasis is primarily by the day-biting mosquitoes, the *Aedes* species (Stolk et al., 2004).

The life cycle of the mosquito-borne filarial nematode includes five developmental or larval stages in a vertebrate host and an arthropod intermediate host and vector as shown in Figure 2.3. However, filarial worms have unique features in their life cycle. They require an arthropod vector for both maturation of their larvae and transmission from one vertebrate to the other (World Health Organization, 2013h). The adult lymphatic-dwelling female worms produce thousands of first-stage larvae called microfilariae which enters and circulates in blood or moves around cutaneous tissues where they are ingested by a blood-feeding insect vector (mosquitoes or flies) (Stolk et al., 2004). The circadian rhythm as they feed correlates with a circadian rhythm of the microfilariae in the circulation at the time when its concentration in blood is highest, as described above on periodicity (World Health Organization, 2013h). This is the time of day when the host-seeking mosquitoes is most active in feeding (Stolk et al., 2004). In the mosquitoes the microfilariae migrate

through the wall of the digestive tract into haemocoel then into specific suitable locations (usually the thoracic muscles, Malpighian tubules or fat bodies) for development to first stage larvae (L1), second stage larvae (L2), and infective third stage larvae (L3). The L3 then migrates to the mouthparts and escapes into or onto the vertebrate host's skin when the arthropod takes a blood meal. L3 is inoculated back into the vertebral host during feeding and the final two stages of development follow (Ash and Schacher, 1971). Between day 9 and 14, L3 undergo moulting to become fourth stage larva (L4), and after approximately 30 days post infection the L4 moults into adult worm. The adults commonly reside in the lymphatics at level 2. The female worms measure 80 to 100 mm in length and 0.24 to 0.30 mm in diameter, while the males measure about 40 mm by 0.1 mm. The life span for the adult worm is estimated to be 5 years and during these years they actively reproduce millions of larvae (Ash and Schacher, 1971, Vanamail et al., 1996).

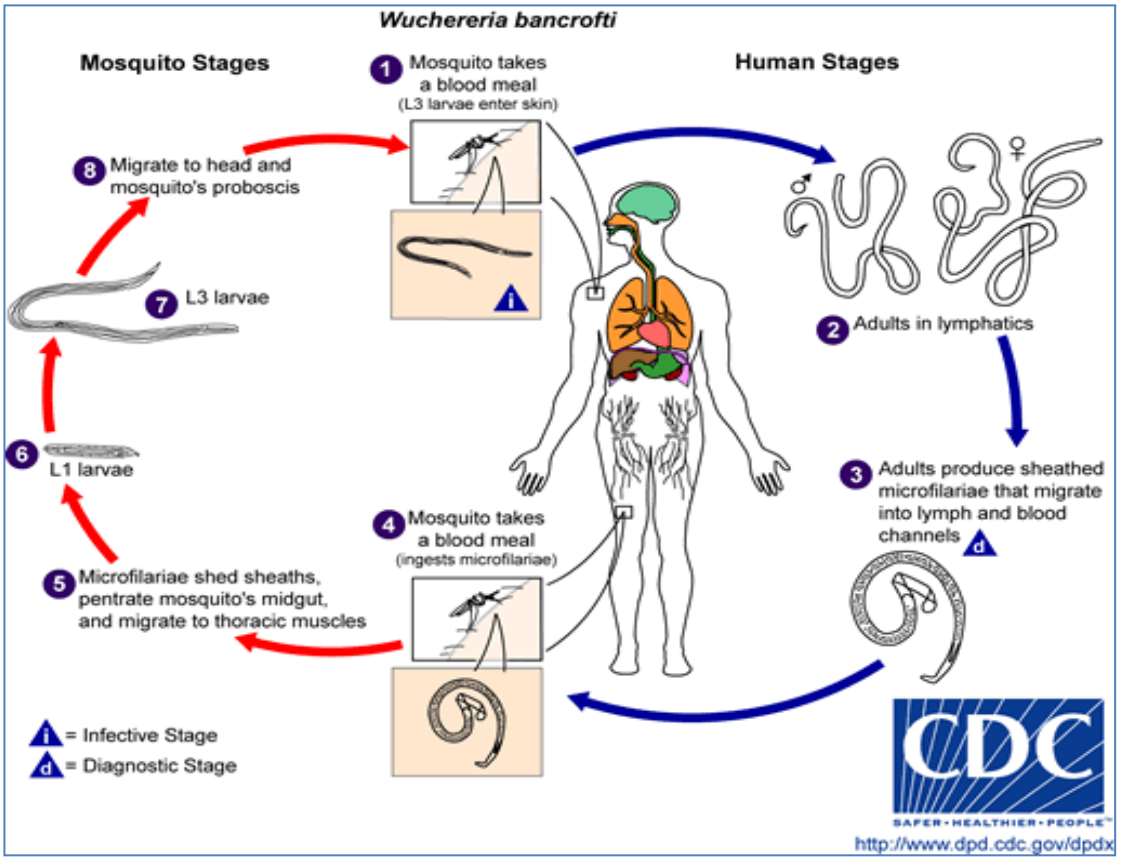


Figure 2-3 The Lifecycle of Wulchereria bancrofti

The figure shows 8 stages of the *W. bancrofti* life cycle. It also clearly shows the infective and diagnostic stages of the life cycle. The adult female in the lymphatic system produces sheathed microfilaria which migrates into the blood and out through a mosquito bloodmeal. The microfilaria matures from larvae 1 to 3 and migrates to the head of the mosquito where it is released into human during another blood meal.

The life cycle of *Brugia brugia and timori are* the same as that of the *Wuchereria bancrofti*. The female worm at stage 3 measures 43 to 55 mm in length by 130 to 170 μm in width, and males measure 13 to 23 mm in length by 70 to 80 μm in width. Adult females produce microfilariae, measuring 177 to 230 μm in lengthand 5 to 7 μm in width, which are sheathed and have nocturnal periodicity (World Health Organization, 2013a). *Mansonella perstans* species can be mistaken for *W. bancrofti* microfilaria. They have a similar lifecycle except *Mansonella* species are found in peripheral blood at any time of the day. The *Mansonella* species are smallerin size and unsheathed (Mathison et al., 2019).

2.3.4 The vectors for lymphatic filariasis

Following the first demonstration that mosquitoes are the main vectors of LF (Manson, 2002), different species of mosquitoes have been tested to determine the main vectors of *W. bancrofti* and other species of LF. Most of the vectors of filariasis depend on the prevailing socio-economic and ecological factors found in various geographical areas. The vectors include *Culex* (*C. annulirostris*, *C. bitaeniorhynchus*, *C. quinquefasciatus*, and *C. pipiens*); *Anopheles* (*A. arabinensis*, *A. bancroftii*, *A. farauti*, *A. funestus*, *A. gambiae*, *A. koliensis*, *A. melas*, *A. merus*, *A. punctulatus* and *A. wellcomei*); *Aedes* (*A. aegypti*, *A. aquasalis*, *A. bellator*, *A. cooki*, *A. darlingi*, *A. kochi*, *A. polynesiensis*, *A. pseudoscutellaris*, *A. rotumae*, *A. scapularis*, and *A. vigilax*); *Mansonia* (*M. pseudotitillans*, *M. uniformis*); Coquillettidia (*C. juxtamansonia*) (Stolk et al., 2004). However, for active transmission to continue, the ability of the mosquito to ingest the microfilaria and the successful development into the infective larvae (L3) is crucial (Snow et al., 2006). In culicine mosquitoes, studies have shown different patterns of infection were the larger the quantity of ingested microfilariae the less successful it is to yield infective larvae and previous entomological studies have highlighted damage of the larvae during uptake (World Health Organization, 2013h). Further the relationship between anopheline species and *W. bancrofti* is known as facilitation because as the number of microfilaria ingested increases, the yield of L3 per microfilaria increases (Pichon, 2002). On the contrary, with *Aedes* mosquitoes, a process called limitation takes place because low densities of ingested microfilariae have a high likelihood of survival.

Overall, compared with other infectious agents transmitted by arthropods, this is an extremely wide range of genera and species with a capacity to transmit microfilariae particularly that of *W. bancrofti*. Mosquitoes belonging to the *Culex pipiens* complex principally transmit the nocturnally periodic form of *W. bancrofti* worldwide. The major vector in the group is *Culex quinquefasciatus*. Zambia has not investigated widely on the major vectors, but an assumption is that anopheline and the culex mosquitoes play a major role (Shawa et al., 2013).

2.3.5 Clinical manifestations and treatment

The adult worm causes damage and blockage to the lymphatic system which manifest in various ways and disease extent. The common diseases or conditions include lymph stasis (elephantiasis/lymphoedema), adenolymphangitis, and lymphangitis. Elephantiasis which is a late stage classical sign, is a painful, disfiguring swelling of the legs and genital organs. It is normally chronic and incurable by anti-filarial drugs but requires other measures such as care of the skin and exercise to increase lymphatic drainage while hydroceles require surgery (Molyneux et al., 2005). Annual treatment of all individuals at risk (living in endemic areas) with recommended anti-filarial drugs such as a combination of either diethylcarbamazine and albendazole, or ivermectin and albendazole (Gabrielli et al., 2011); or the regular use of DEC fortified salt can prevent occurrence of new infection and disease (Dubray et al., 2020, Specht et al., 2019). The treatment significantly reduces the intensity of microfilaremia and this has implications on elimination of lymphatic filariasis. Treatments are usually done yearly as community-wide distribution to eligible populations (Gabrielli et al., 2011). In areas where LF is co-endemic with *Loa loa*, IVM and DEC are not recommended as they cause *L. loa* encephalopathy which can adversely affect the NTD programme (Wanji et al., 2018, King et al., 1992). In these areas integrated vector control programmes are highly recommended with albendazole monotherapy once or twice a year (Gabrielli et al., 2011).

The clinical presentation of LF manifests in various ways depending on the stage, the species of the parasite and the endemic area. In addition, individuals living in endemic areas fall under five sub-groups namely:

2.3.5.1 **Acute symptomatic**

This is a group which is mainly induced by adult worms located in the lymphatics characterised by fever, inflammation of the lymphatic vessels (lymphangitis) and lymph nodes (lymphadenitis). The symptoms are periodic, acute and recurrent in nature (King et al., 1992). The death of the adult worm leads to the syndrome called acute dermatolymphangitis (ADLA) and is suggested to be a result of secondary bacterial infection. Acute dematolymphangitis is often accompanied by distal oedma of the affected leg with exfoliation of the skin once odema resolves (Bockarie et al., 1998).

2.3.5.2 **Tropical pulmonary eosinophilia**

About 1 million individuals present with the syndrome known as tropical pulmonary eosinophilia (TPE) (Bockarie et al., 1998) which is characterized by nocturnal cough or wheeze resembling an asthmatic attack (Addiss and Brady, 2007). The chest radiographs show nodular diffuse lesions and include elevated peripheral blood eosinophilia of greater than 3000/mm³ with high levels of antifilarial antibodies (IgG) and serum IgE (King et al., 2001). This is as a result of hyper-responsiveness of the human host to the parasite, especially microfilariae. TPE responds well to DEC (Bockarie et al., 1998).

2.3.5.3 **Chronic lymphatic filariasis**

These are individuals that develop pathology such as elephantiasis or lymphedema which mainly affects the lower limbs though can also affect any part of the body such as the breast, penis, scrotal sac, arms and vulva. The lymphatic filariasis hydrocoele usually has straw-colored fluid. In men, the preferred site for *W. bancrofti* is the in the spermatic cord and scrotal swelling could be a good indicator of adult worm death (Jha et al., 2020).

2.3.5.4 **Endemic normal**

A proportion of individuals living in endemic areas with no clinical and parasitological evidence of infection (World Health Organization, 1984) are presumed non-infected as the gain of infection rate levels off after reaching adulthood but the rate of loss of infection is age dependent as was seen in a study conducted in India (Day, 1991). This can be attributed to the development of immunity due to repeated exposure.

2.3.5.5 **Asymptomatic filarial group**

These unlike the endemic normal test positive to the circulating filarial antigen test but are clinically asymptomatic and remain so for many years. Recent studies have shown that this group may present with sub-clinical lymphatic pathology following immunological damage induced by immune complex deposits in the renal glomeruli and are common with *W. bancrofti* (Ottesen et al., 1997).

The recommended drug for LF since the 1940s has been diethylcarbamazine citrate administered as single dose of 6 mg/kg/day for 12-14 days (World Health Organization, 1984). However, this does not completely cure the disease but shows great reduction in the microfilaria. DEC kills the microfilaria and some of the adult worms (Bockarie et al., 1998). Studies have also shown that 1-day treatment is as effective as the 12-day regimen (Kisoka et al., 2014). Lymphoedema and elephantiasis are not indications for DEC treatment because most people with these symptoms in most instances would have sought medical treatment and are no longer actively infected with the filarial parasite because DEC clears the infection. However, there is little evidence that DEC alters the course of acute adenolymphangitis or results in clinical improvement of longstanding lymphedema, elephantiasis, or hydrocele. Albendazole 400 mg is usually administered with either DEC or ivermectin (Gabrielli et al., 2011) due to itsmicrofilaricidal effects. The combination with albendazole provides better mf clearance of up to 99% and subsequently a reduction of mf in mosquitoes (Koroma et al., 2013) and has added advantage of killing intestinal worms. A previous study by Brazilian investigators demonstrated that up to 50% of adult worm nests are completely inactivated by a single-dose combination of ivermectin and diethylcarbamazine (Dreyer and Coelho, 1997). A recent study of individuals with microfilaremia in Egypt reported that 90% of the worm nests remained suppressed 12 months after co-administration of DEC (6 mg/kg) and albendazole (400 mg) (Mani et al., 2004). These antifilarial drugs currently being used are predominant against the larval offspring of the parasite. This can form the basis of the global programme to eradicate LF. These drugs could greatly improve the prospects of programme closure (Bockarie et al., 2009b, Taylor et al., 2010) in that a reduction inthe micro filarial reservoir by mass chemotherapy interrupts transmission and vectorcontrol can eliminate infection (Bockarie et al., 1998).

There are drugs like doxycycline 200 mg/day for four, six or eight weeks which are also used as individual drug in management of *W. bancrofti* and results in long term sterility of the worm and eventual death of the adult worm (Debrah et al., 2006, Permana et al., 2019, Wan Sulaiman et al., 2019). The use of doxycycline has substantial improvement in lymphatic pathological features and decrease lymphedema and hydrocele (Molyneux and Zagaria, 2002). There is a sustained reduction in the larvae and, most notably, the adult worm activity (Taylor et al., 2010). The benefit of doxycycline has, therefore, been suggested to lymphedema patients without active infection and is better than present morbidity management on the basis of hygiene and self-care (Debrah et al., 2006). It is recommended for use in combination with ivermectin 200-400 µg/kg, in areas non-endemic of *Loa loa*. However, a 4-6-week course of doxycycline is not applicable for MDA strategy because of both the logistical issues and the contraindication in children younger than 8 years and pregnant women (World Health Organization, 2013e, Debrah et al., 2006).

In morbidity control and treatment, to prevent lymphoedema from getting worse, it is recommended that patients are referred to a health facility where basic principles of care such as hygiene, exercise, physiotherapy and treatment with doxycycline 200 mg/day for 6 weeks can be prescribed (Debrah et al., 2006, Permana et al., 2019, Specht et al., 2019). Doxycycline is also recommended as the drug of choice following surgical hydrocelectomy and in patients with tropical eosinophilia. This is administered in combination with ivermectin. Moxidectin, a relatively new drug but safe drug to use during MDAs because it also reduces microfilarial loads and transmission to a greater extent than does ivermectin (Dadzie et al., 2018, Gebrezgabiher et al., 2019, World Health Organization, 2013e).

2.3.6 Diagnosis of lymphatic filariasis

Based on the guidelines and protocols from the World Health Organisation mapping, monitoring and evaluation of LF programmes is possible (World Health Organization, 2013a, World Health Organization, 2013h). Diagnosis includes detection of microfilaria (mf) by microscope and counting chambers examination of stained blood smears and detection of circulating filarial antigen (CFA) (Gyapong and Twum-Danso, 2006) in human blood using an immunochromatographic test

(ICT) (Ottesen et al., 1997). ICT is a sensitive and specific biomarker for the presence of *Wucherera bancrofti* parasite responsible for more than 90% of the disease globally (Michael et al., 1996) and is more sensitive than thick smear microscopy as it detects more than 80% of the blood smear positive results while blood smears only detect 15% of the ICT positive results (Gass et al., 2012). CFA is convenient because the nocturnal periodicity is not a factor in its use and does not require electricity, microscopist or special equipment (Weil et al., 2013). The tool is widely used as an epidemiological tool to detect endemicity, assess the success in elimination of LF and detect active filarial infections in individuals suspected to have LF. However, ICT has limitations by its inability to detect infection prior to the development of adult parasites, a process that may take up to 18 months following exposure to infective stage larvae (Steel et al., 2013). Another diagnostic tool, Alere Filariasis Test Strip, has been developed to be the next generation filarial antigen test to improve on the test card. It has significant technical and practical advantages over the CFA test card with improved sensitivity and a longer shelf life at ambient temperatures with cheaper purchase and transportation costs (Weil et al., 2013).

The gold standard for determination of active mf in blood is the measurement of mf under a microscope using giemsa stained thick blood film and PCR (Gass et al., 2012). Zambia has used the counting chamber technique for mf examination under a microscope. Nucleopore or membrane filtration technique has been used to measure the concentration of mf in blood specimen to increase sensitivity. Other tests used in diagnosis of LF include the antibody detection which has been available since 1960 and are based on crude filarial antigens (Steel et al., 2013). However, the antibody assays based on parasite extracts suffer many limitations with regards to paucity of parasite material, standardisation and assay specificity which assays based on recombinant filarial antigens should address and provide useful tools for diagnosis and surveillance of LF (Lammie et al., 2004). More useful are recombinant antigens and assays based on Bm14, WbSXP, or BmR1 demonstrate adequate sensitivity for field use and specificity (Lammie et al., 2004, Steel et al., 2013).

Some other methods involving entomological studies have been used in the diagnosis and monitoring of LF. Mosquitoes are collected, dissected and examined for infective larvae but this requires a lot of technical expertise. The number of

mosquitoes that can be processed using this technique was estimated to be about 35 per person-hour and is slower if mosquitoes are preserved in alcohol. Additionally, detection of parasite DNA in human blood or in mosquitoes by PCR is more sensitive and specific and hence a powerful tool for evaluation and monitoring of community based filariasis control and elimination programmes. Xenomonitoring is a term used for this approach of monitoring filariasis prevalence in the human population via vector sampling and assays (Specht et al., 2019, World Health Organization, 2013h, World Health Organization, 2010).

2.3.7 The global programme to eliminate lymphatic filariasis strategy and progress

In the elimination of a disease in certain key areas fall on availability of the right tools, clearly understood biological factors of the disease and organisms, technical factors and political will. These are essential requiring appropriate actions to be undertaken. Firstly, the societal and political criteria for elimination and eradication; secondly, how is eradication defined including the biological criteria; thirdly, what is the cost and lastly when should eradication be implemented and not just elimination from one local area?

Two decades ago, the greatest barriers to LF elimination were: lack of tools (safe, single dose, treatment regimens capable of reducing microfilaremia to zero or near-zero levels for 1 year or more, diagnostic techniques for field diagnosis of infection by simple, finger-prick, anytime-of-day antigen-detection tests and for clinical diagnosis by ultrasound identification of living adult parasites) necessary to interrupt transmission and halt disease progression; lack of understanding of disease dynamics and pathogenesis; and lack of public health awareness of LF impact and public commitment to overcome it (Ottesen, 2000). The fact that LF is almost exclusively a parasite of humans, its inability to amplify its numbers in the vector (mosquitoes) and its relatively inefficient mechanism of transmission favoured its possibility of elimination (Ottesen et al., 1997). In 1997, a resolution was passed calling for the elimination of LF as a public health problem and heightened momentum to the global elimination of LF (World Health Organization, 1997b). This landmark resolution followed the 1993 declaration by the International Task Force for Disease Eradication (ITFDE) that LF was one of the six eliminable diseases

Recommendations of the International Task Force for Disease Eradication (Centre for Disease Control, 1993).

In 2000, the Global Alliance for the Elimination of LF (GAELF) launched the Global Programme to Eliminate LF (GPELF) by 2020. The goal was to interrupt transmission of infection between mosquitoes and humans mainly through mass drug administration of DEC or ivermectin with albendazole, and to alleviate and prevent both the suffering and disability caused by the disease (World Health Organization, 2012a). GlaxoSmithKline (GSK) committed to donate albendazole to WHO for use by any country that needs it. And later Merck & Co. Inc., announced its commitment to expand the ivermectin (Mectizan) donation established for the control of onchocerciasis (river blindness) to cover countries that had both LF and onchocerciasis (Mectizan®, 2003, Molyneux and Zagaria, 2002). Partnerships were developed that led to the creation of the Global Alliance to Eliminate LF (GAELF) in 2002. The partnerships for GPELF include WHO for policy and guidelines; GAELF for advocacy and fundraising; national governments or programmes for coordination and implementation, NGOs to assist ministries of health; academics for operational research and evidence, donor partners for financial assistance; and pharma for drug donations. These will contribute to a future free of lymphatic filariasis, reduce poverty and bring better health to poor people, prevent disability, strengthen health systems and build partnerships

The GPELF is part of integrated efforts to prevent and treat NTDs, in which MDA, vector control and morbidity management are increasingly integrated and delivered as multi-intervention packages at the global, national, and local levels (Ichimori et al., 2014). GPELF prevented development of LF in 6.6 million born babies between 2000 and 2007, thus averting nearly 1.4 million hydrocoeles, 0.8 million cases of lymphoedema and 4.4 million cases of subclinical disease (Taylor et al., 2010).

Early support by governments to eliminate LF was an indication that there was political will with additional support coming from the Arab Fund for Economic and Social Development (AFESD) United States of America Centre for Disease Control (USA CDC) and the United Kingdom Department for International Development (DFID). These seek to work in partnership with governments

committed to these targets, with business, civil society and the research community. They also work with multilateral institutions such as the World Bank, United Nations agencies such as the World Health Organization, Global Health NTD Support Centre, Gates Foundation and the European Community and ensure the process of change brings benefits to all people, particularly the poorest, and for this reason is a strong supporter of lymphatic filariasis elimination (Ichimori, 2014, Molyneux et al., 2005, World Health Organization, 2012a, World Health Organization, 2013g). Bill and Melinda Gates Foundation in November 2000 made a generous contribution of US$20 million into a Trust Fund in the World Bank towards the elimination of LF (World Health Organization, 2002).

2.3.8 Interrupting transmission

Understanding the efficacy of microfilaricidal drugs is important in guiding the global programme for the elimination of LF as a public health problem. Combined treatment with DEC plus ivermectin, DEC plus albendazole and ivermectin plus albendazole resulted in average microfilarial intensity decreases that were 0.7%, 4.6% and 12.7% of the pre-treatment values, respectively. Drug combinations containing DEC are the most effective against microfilarial prevalence and intensity relative to single drugs or other combinations (World Health Organization, 2011). Simultaneous treatment in children with ivermectin and albendazole is more effective than treatment with ivermectin alone with no apparent increase in severity of adverse reaction (Gabrielli et al., 2011, World Health Organization, 2013a). Where onchocerciasis is co-endemic, the regimen is ivermectin 200 – 400 μg/kg plus albendazole 400 mg; elsewhere, the regimen recommendation is DEC 6 mg/kg plus albendazole 400 mg. In areas co-endemic with *Loa loa* pre-treatment diagnosis is necessary for loiasis, especially in endemic West and Central Africa due to the possibility of serious or fatal encephalopathy, in people with > 8,000 Loa loa microfilariae mL/blood (World Health Organization, 2017d, Wanji et al., 2018). An integrated strategy of vector management and albendazole monotherapy MDA for eliminating LF in loasis-endemic areas has been recommended (World Health Organization, 2017d).

Control of LF using annual MDA is one of the cheapest and most beneficial disease control strategies. Administration of a single dose of antifilarial drugs to

entire community (MDA) once yearly for five years is a recommendation for all the districts endemic of LF. This is because of the asymptomatic nature of LF infections. Finding the infected persons to be treated alone at this stage would take a very long time. The drugs can also be administered safely in both the infected and non-infected individuals (Gabrielli et al., 2011). With MDA, the microfilaria will be cleared and will not be present in the blood for mosquitoes to transmit. MDA repeated annually over 5-6 years interrupt transmission leading to future generation is free of LF (Molyneux et al., 2005). Everyone in the community should receive the single dose of the drug combinations (see Table 2-1) on a full stomach except pregnant women, children below two years and those who are very sick from other illnesses (Gabrielli et al., 2011).

Table 2-1Table showing the doses of Albendazole, DEC and praziquantel for the different age groups

Age in years	DEC		Albendazole	Ivermectin
	Dose	No. of Tablets (100 mg)		Dose pole is used
<2	Nil	Nil	Nil	Nil
2-5 years	100 mg	1	1	Nil
6-14 years	200 mg	2	1	Use dose pole
≥15years	300 mg	3	1	Use dose pole

(Gabrielli et al., 2011)

The dose of different drugs is administered using dose pole and according to age group.

Three annual rounds of integrated MDA with ivermectin and albendazole in 12 districts that are co-endemic for onchocerciasis and LF with good geographical, epidemiological (or programmatic) and drug coverage reduced microfilaremia prevalence to 0.3% and average microfilarial density was 0.05 mf/ml an overall reduction of 87.5% and 95.5% respectively in Sierra Leone (Koroma et al., 2013). The annual MDA against LF yield significant social and economic benefits at a very low cost (Ottesen et al., 1997).

There is very little if any drug reactions from treatment with ivermectin which is transient and generally mild and mainly associated with the microfilarial concentration in loasis non-endemic places (Gabrielli et al., 2011). There is usually no local reaction indicative of drug efficacy against the adult worm (Hotez and Aksoy, 2017). Despite the good tolerability, DEC can produce adverse reactions such

as drowsiness, nausea, fever, headache, arthralgia, lymphangitis, lymphadenitis, orchitis, epididymitis and other symptoms. This is associated with the dose-related chemical toxicity of the drug and occasionally with the death of the parasite (Dreyer and Coelho, 1997). In Brazil, following the first round of MDA, two areas with prevalence of 6.2% and 10.4% respectively experienced the following adverse reactions; drowsiness, nausea, headache and dizziness while the second area saw more of abdominal discomfort/pain in addition to the other symptoms. Local reactions were less than 3% in both areas and were mainly of scrotal swelling, lymphangitis and lymphoedema (Ottesen, 2000).

2.3.9 Brief history of lymphatic filariasis in Zambia

At the beginning of my research, little had been reported about LF in Zambia despite the country lying within the endemic belt. From the published literature it has been reported that in some parts of the country elephantiasis had been seen in some communities described this feature as “serenje and feira legs” (Shawa et al., 2013, Silumbwe et al., 2019). They were given those names because the people who presented with these features came from the two districts called Serenje and Feira (Feira is now called Luangwa) between 1930 and 1940. However, despite this physical evidence no *W. bancrofti* had been reported and the elephantiasis was said to be non-filarial. To date these two areas have continued to record cases that have tested positive to CFA and microscopy for microfilaria. In 1946, Buckley isolated microfilaria for *W. bancrofti* from 3 patients in hospital, one each from Ndola, Kasama and Lusaka, but these were of foreign nationality. In further attempts to isolate the parasite from nocturnal blood of individuals from Luangwa, Buckley only isolated *Mansonella perstans* which is another form of human filaria (Buckley, 1946).

Hira was the first to report of a confirmed *W. bancrofti* case in Zambia in 1975 in a 25-year-old in Luangwa district who presented with inguinal and leg swellings Later he isolated the parasite from many more Zambians confirming the endemicity of LF in the country. The knowledge of disease endemicity, prevalence and the focal transmission requiring focal mapping therefore stems way back in the 20th Century. However, the accurate distribution and prevalence of the disease was still lacking until in the 21st Century when a nationwide mapping was conducted. The mapping

activities started in 2003 to 2005 in a few isolated districts where LF cases and positive malaria cases had been reported before. However, this was going to compromise the national control programme with appropriate strategies and further studies were required to cover the whole nation as LF had an elimination target. The nationwide mapping using ICT for CFA in all 72 districts then and confirmed endemicity of LF in 56 districts (Mwase et al., 2014).

2.4 Urogenital and intestinal schistosomiasis

2.4.1 General information

This section of the literature review introduces the two main types of schistosomiasis, the evolution history, burden, transmission and the intermediate hosts. It will also look at the strategies currently in place to combat schistosomiasis.

Schistosomiasis, also known as Bilharzia, is a chronic disease caused by past or present infection with parasitic blood flukes of the class of trematodes. Schistosoma, commonly known as blood flukes are parasitic flat-worms which are responsible for a highly significant group of infections in humans termed schistosomiasis. There are five species that infect human typically more than others and include *Schistosoma* species: *S. mansoni, S. haematobium, S. japonicum, S. mekongi* and *S. intercalatum* (Sturrock, 2001). The three major parasites that affect human beings are *S. mansoni, S. haematobium* and *S. japonicum* and are prevalent in many parts of Africa, the Middle East, South America, and Asia with more than 1200 million infected worldwide (Ross et al., 2001). Schistosomiasis manifest differently in individuals and at different levels affecting health and performance due to substantial growth retardation, anaemia, cognitive impairment and memory deficits .The two main types of schistosomiasis are: Intestinal schistosomiasis caused by either *S. mansoni* or *S. japonicum* infections and affects the gastro intestinal tract, and urogenital schistosomiasis which affects the genital and urinary tract systems mainly caused by *S. haematobium*. Depending on stage of the disease, schistosomiasis is categorised as mild schistosomiasis with small impact on performance, intermediate with irreversible effects that moderately impair quality of life; or advanced with significant chronic disabling impact. Fortunately, with renewed prominence and increased appreciations of the health and social burden the advancement in research, new technology, sensitive diagnostics and treatment will

make schistosomiasis a problem of the past (King et al., 2011). There are new inexpensive approaches such as deworming of school-age children from 5 to 14 years old, that are making parasite treatment and transmission control increasingly more accessible (Molyneux et al., 2005).

2.4.2 The burden of schistosomiasis

Schistosomiasis is endemic in 70 developing countries, and more than 200 million people are infected worldwide. *S. mansoni* occurs in Africa, Middle East, the Caribbean, Brazil, Venezuela, Suriname; *S. haematobium* occurs in Africa and the Middle East, whilst *S. japonicum* only occurs in China, Indonesia and the Philippines (Chitsulo et al., 2000). The map in Figure 2-4 shows the global disease distribution of schistosomiasis by country and continent. The map therefore indicates that Africa has the highest prevalence and the disease is endemic in more than 90% countries.

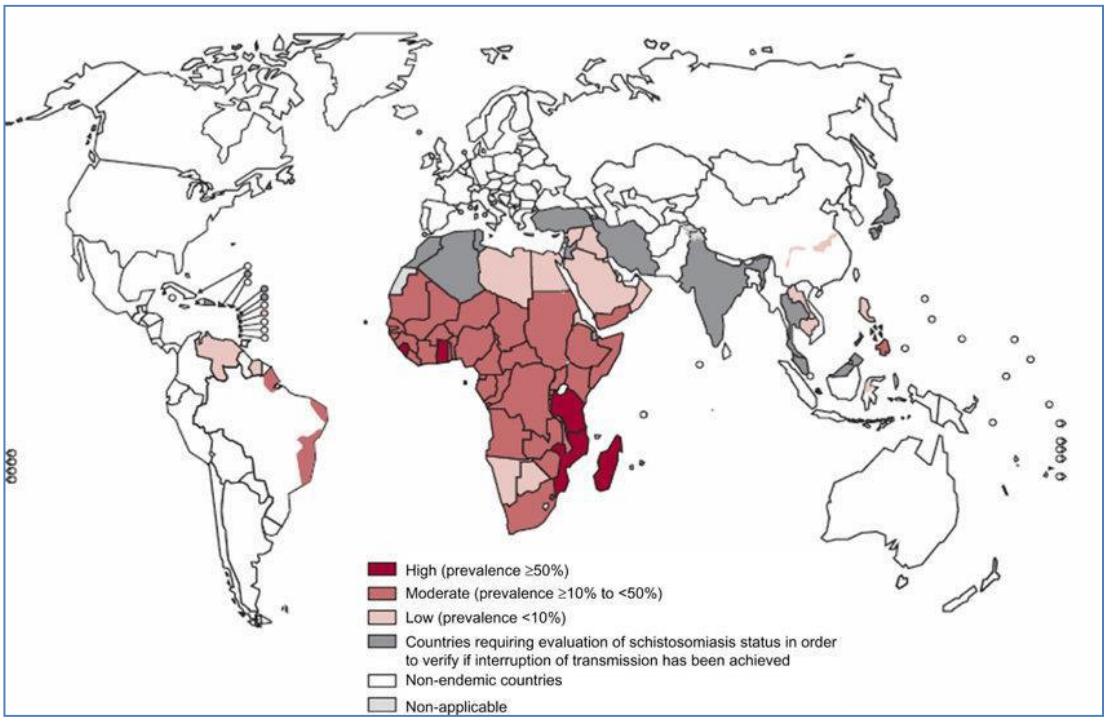


Figure 2-4 A map showing the world-wide distribution of schistosomiasis

Global map of schistosomiasis showing the endemicity status. Zambia is moderately endemic like most Sub-Saharan African countries. Very high prevalence in Madagascar, Mozambique and Tanzania (World Health Organization, 2013f).

Most infected people live in poor communities without access to safe drinking water and adequate sanitation. An estimated 90% of infected individuals live in Sub-Saharan Africa as shown on the map in Figure 2.4, where up to 20 million people also suffer severe, chronic health consequences of the disease and a further 20,000

people die every year from schistosomiasis-related health problems (World Health Organization, 2013f), such as bladder cancer, kidney failure and liver or spleen damage (Chitsulo et al., 2000). Tchuem Tchuente (Tchuem Tchuenté et al., 2017) showed high prevalence of schistosomiasis among pre-school age children.

2.4.3 The parasite and its life cycle

The schistosomes require two hosts in their life cycle Figure 2.5. The adult male and female worms live within the veins of the human host where they mate and produce fertilised eggs which are expelled in the faeces or urine of the host or are retained in host tissue where they induce inflammation and then die. These eggs whether excreted or retained in the body die within 1-2 weeks. The expelled eggs that reach fresh water hatch and release free-living ciliated miracidia into fresh water. Miracidia survive for 8-12 hours in fresh water during which time it has to penetrate the snail. They are mobile in water and infect the snail which is the intermediate host. Whilst in the infected snails, miracidia undergo asexual replication through the mother and daughter sporocysts stages and release tens of thousands of quantities of free-swimming larvae called cercariae. The asexual portion of the cycle lasts between 4 to 6 weeks before the release of the infective cercariae and remain infective in water 1-3 days (Colley et al., 2014). The cercaria penetrates the skin of humans, the definitive host. The cercariae migrate in the body and transform progressively into adult schistosomes and the cycle continues (Colley et al., 2014).

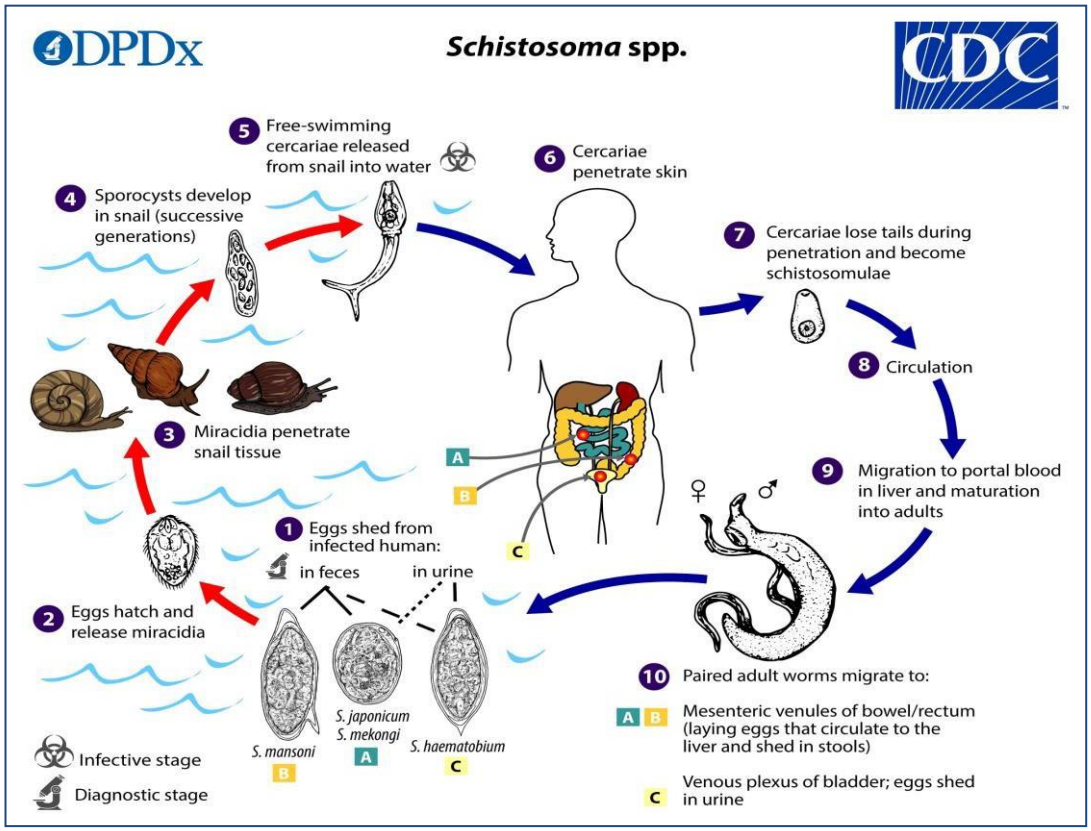


Figure 2-5 The lifecycle of the three main Schistosoma species that infect humans

The adult male and female worms live within the veins of the human host where they mate and produce fertilised eggs which are expelled in the faeces or urine. The expelled eggs that reach fresh-water hatch and release free-living ciliated miracidia into fresh water. Miracidia survive for 8-12 hours in fresh water during which time it has to penetrate the intermediate host the snail. Snails release cercaria which penetrates humans and migrate to the portal and matures into adult (Centre for Disease Control, 2019)

Depending on the species of the snail, parasite and environmental conditions, this phase of development can take 3 weeks in the tropics and 4-7 weeks or longer elsewhere. Schistosomiasis occurs in focal pockets and is closely linked to the presence of water bodies that harbour susceptible species of snails.

2.4.4 Vectors of schistosomiasis

Understanding the schistosome lifecycle and the parasite's movement between intermediate and definitive hosts is fundamental to the control and elimination of human schistosomiasis. Studies have shown that each species of schistosomiasis has a specific range of suitable snail hosts, and so their distribution is defined by their host snails' habitat range (Colley et al., 2014). Table 2-2 below is a summary of the schistosomiasis intermediate host, the snail.

Table 2-2 Global distribution of intermediate hosts of schistosomiasis

Vector/snail species	Parasite	Geographical region	Reference
Biomphalaria (aquatic freshwater)	*S. mansoni*	Sub-Saharan Africa	(Colley et al., 2014, Stensgaard et al., 2016)
Bulinus (aquatic freshwater)	*S. haematobium*	Africa, the Middle East, South America, South East Asia,	(Colley et al., 2014)
Oncomelania (amphibious freshwater)	*S. japonicum*	Africa, the Middle East, South America, South East Asia,	(Colley et al., 2014)

The intermediate snail species in Africa is *Biomphalaria* for *S. mansoni* and *Bulinus* for *S. haematobium*

In Zambia the identified snail species are *Bulinus* (Physopsis) *africanus* and *B.* (P) *globosus* which are responsible for the transmission of the infection to humans (Ross et al., 2001). These snails prefer habitats retaining water for the major part of the year and are found in both rural and urban areas. The urban situation could be attributed to the continuous peri-urbanisation that is going on in the country where there are poor or non- existent sanitary facilities and lack of clean water supplies.

2.4.5 Clinical manifestation and treatment

Most of the clinical manifestation of schistosomiasis is because of the immune response to the eggs that are released by the adult worms which are not expelled in stool or urine and lodge in the body tissues where they die. In most instances there is granuloma formation and fibrosis leading to morbidity and subsequently death after years of suffering (Chitsulo et al., 2000). The symptoms are related to the number and location of the eggs. The clinical manifestations do not commence immediately after an infection but in some cases within days of infection, they

may develop a rash or itchy skin and within 1-2 months of the infection, symptoms may develop including chills, fever, cough and muscle aches. Further, without treatment, the life span of the adult worm is 3 to 5 years and schistosomiasis can persist from being acute which lasts to chronic infection (Ross et al., 2001). In many respects, Schistosoma infection can be seen as an acute communicable disease that transitions into a chronic non-communicable disease in later life. It is therefore viewed as a two-health risk which is the immediate and concurrent cause of disease due to acute inflammation, and the dominant risk factor for non-communicable morbidity and disability in later life (King et al., 2011).

In urinary schistosomiasis, the eggs cause damage to the urinary tract and blood appears in the urine. Urination becomes painful and there is progressive damage to the bladder, ureters and kidneys. Bladder cancer is common in advanced cases. These symptoms lead to anaemia, malnutrition, stunted growth and impaired cognitive development, and reduced capacity to work (World Health Organization, 2013f). The infection can also affect both male and female reproductive organs and although predominant in adult women, case reports in girls younger than 15 years of age have been documented (Hotez et al., 2019). Every female genital organ (hymen, clitoris, vulva, vagina, uterine cervix, uterine body, Fallopian tubes and ovaries) can be affected by schistosomiasis(Stothard et al., 2020, Christinet et al., 2016, Hotez et al., 2019, Rutty Phiri et al., 2020, Sturt et al., 2020). Genital schistosomiasis causes vesico-vaginal fistula, contact bleeding, dysparemia, genito-pelvic discomfort in cervical involvement, delayed puberty, ectopic pregnancy, infertility and also increased chance of human papilloma virus (HPV) and HIV infection. In the Christinet specific review on female genital schistosomiasis (FGS) attributed to Schistosoma haematobium in the anatomopathological series, among those 170 million infected by *S. haematobium* globally, half of them are women (85 million) and at least one-third of those women may suffer from FGS. Uterine and cervical schistosomiasis is the most prevalent form in Zambia (Christinet et al., 2016). Though previously not reported on, the genital schistosomiasis is common. Tanzania has reported the occurrence of genital schistosomiasis to be comparable with urinary schistosomiasis including the affected organs and further studies have shown that infection in the female genital organs occurs with variation in the

vascular tissues during puberty and a shift in the direction of flow of blood when one is pregnant (Christinet et al., 2016, Sturt et al., 2020).

It is also very important to assess antenatal infections as it may have implications on the efficacy of early childhood vaccinations. Studies suggest that neglected tropical diseases (NTDs) significantly impair response to standard childhood immunizations because chronic trematode, nematode and protozoan infections results in decreased vaccine efficacy. The soluble parasite antigens present in pregnant women with multiple parasites cross the placenta barrier and polarise foetal immune response which later has a significant impact on later vaccination response as is seen in acquired malaria infections that affects subsequent immune response to vaccination (Labeaud et al., 2009). Exposure to schistosomiasis at an early age may be a risk factor for chronic and severe morbidity in school age years (Stothard et al., 2011a, Stothard et al., 2011b). In male genital schistosomiasis, there is presence of ova in semen with haemospermia, erectile dysfunction, painful ejaculation, infertility, acute orchitis, chronic prostatitis, cancer of the testis and increased shedding of HIV (Wall et al., 2018, Feldmeier et al., 1999, Kayuni et al., 2019, Kini et al., 2009).

The clinical manifestations in intestinal schistosomiasis are also progressive and devastating and include enlargement of the liver and spleen as well as damage to the intestines caused by fibrotic lesions around the schistosomes eggs lodged in these tissues and hypertension of the abdominal blood vessels. Repeated bleeding from these vessels lead to blood in stool and this can be fatal. The main cause of intestinal schistosomiasis is *S. mansoni* and *S. japonicum*, however, *S. intercalatum* infects the lower intestinal tract .(Stothard et al., 2011a, Sturrock, 2001)

The good news is that infections with all major Schistosoma species can be treated with praziquantel which is very effective against the adult worm except it requires the presence of mature antibody response to the parasite. This is key when it comes to treatment as the timing between exposure and treatment is an important factor. In the management of schistosomiasis, this aspect should be taken into consideration including prophylaxis as praziquantel should be taken 6-8 weeks after exposure to contaminated freshwater. Treatment with praziquantel has been the

mainstay of schistosomiasis since 1984 and has been used for PC since 2006 (Gabrielli et al., 2011).

There is limited evidence of parasite resistance to praziquantel and so it remains the drug of choice for treatment of schistosomiasis When it comes to treatment, praziquantel is used for treatment of the three principal Schistosoma species that cause human disease, *Schistosoma haematobium*, *S. mansoni*, and *S. japonicum* (Bustinduy et al., 2016*).* PZQ damages the adult worm tegument by disrupting calcium ion channels, the damage which may facilitate subsequent immunological attack and later clearance of the parasite. It has very little or no effect on immature worms. In *S. mansoni* infected patients, it alters significantly the immune response and generates a reversal of the level of fibrosis ameliorating the disease complication (Oliveira et al., 2006). In children, slow serum levels of transforming growth factorβ (TGF-β) seen after treatment with praziquantel is significant as TGF-β has shown to be critical in the *S. mansoni* embryo growth (Freitas et al., 2007, Hafiz et al., 2015). This requires further studies as it could just be the key to the development of vaccines which could be a permanent solution to he problem of schistosomiasis control and elimination (Loverde et al., 2007).

Praziquantel is 2-(cyclohexlcarbonyl)-1,2,3,6,7,11b-hexahydro-4Hpyrazino [2, 1-a] isoquino-4-one with the molecular formular; $C_{19}H_{24}N_2O_2$. It contains 600mg of praziquantel. The recommended dose for treatment of schistosomiasis is 40-60 mg per body weight (Gabrielli et al., 2011) and its bioavailability is enhanced by concomitant administration of food (Chitsulo et al., 2000, Colley et al., 2014). In general, Praziquantel is very well tolerated. After a single administration of praziquantel, the parasitological cure rate measured as interruption of eggs excreted is usually between 70 and 100 % (Bustinduy et al., 2016).

The impact of treatment at regular intervals has shown to go beyond that of isolated administration of praziquantel and to be significantly associated to the reduction of the indicators of schistosomiasis (World Health Organization, 2013f). With the “value for money” concept and the cost effectiveness of integrated NTD control programmes, praziquantel is recommended to be co-administered with albendazole/mebendazole and ivermectin by WHO (Gabrielli et al., 2011). It should

also be available in dispensaries for treatment of suspected cases and not just when used for PC.

Other medicines used in treatment of schistosomiasis include niridazole, metrifonate and oxamniquine given as a single oral dose (Barsoum et al., 2013, Davis and Bailey, 1972).

2.4.6 Diagnosis of schistosomiasis

Diagnosis of schistosomiasis is diverse ranging from microscopy to immuno assays and imaging and referred to as parasitological and immunological tests. The microscopic detection of eggs in parasitological tests is the primary method for suspected schistosome infection which has been used commonly. The choice of sample and test depends on the species causing the infection and this is because the adult stages of *S. mansoni, S. japonicum, S. mekongi and S. intercalatum* reside in the mesenteric venous plexus of infected hosts and eggs are shed in faeces while that for *S. haematobium* adult worms are found in the venous plexus of the lower urinary tract and eggs are shed in urine (Chitsulo L, 1995).

The Kato Katz assay is used to diagnose schistosomiasis in endemic areas especially those with higher rates of transmission and is recommended by WHO. Therefore, stool specimen is examined for eggs using the Kato Katz technique and it can be used both in the field or the laboratory (Colley et al., 2014) and used in Zambia *for S. mansoni* infections and *S. japonicum* while urine specimen is examined using the filtration technique also involves the microscopic examination of a filter used to collect the eggs to detect *S. haematobium* eggs in urine. Another key principle in these microscopic examinations is the timing when to collect the specimen. The best time for stool collection is in the morning for examination before the end of the day. It has high specificity and low sensitivity (Nelwan, 2019). The urinary excretion of these eggs follows a daily rhythm with the peak around noon and hence the best time to collect specimen is between 10am and 2pm. Physical exercise combined with fluid intake increase egg output significantly. Haematuria on the other hand can bedetected by direct observation of the large urine specimen which appears reddish in colour. It is an important sign of heavy infection with *S. haematobium.* Detection of macrohematuria requires the use of reagent strips. The method is easy to use and can be done at any time of the day (Colley et al., 2014).

Rapid-format immunological tests for schistosomiasis recently developed include bilharzia urine circulating-cathodic-antigen (CCA) strip test which detects the schistosome circulating-cathodic-antigen present in all Schistosoma species in urine of an infected individual. It has been detected that successful treatment against SCH may reduce the level of CCA in urine to background levels in a few days. For *S. mansoni* and *S. japonicum*, CCA levels in urine are high and hence very sensitive for the two parasites. The test strip has some limitations because it is less sensitive to S. *haematobium* and the CCA level is much lower. In addition, cases of urinary tract infection may lead to false positives due to cross reactivity of the antigen (de Sousa et al., 2019, Sousa et al., 2020).

The new test performs well to detect schistosomiasis in children making it easier for field work especially that some children fail to produce stool but would easily produce urine. Unfortunately, it cannot be used to detect soil-transmitted helminths and where the two studies are combined the child still has to produce stool. An evaluation on the performance and diagnostic accuracy of four tests – the carbon CCA test strip used in laboratory, the cassette format CCA test meant for field work and ELISA in comparison to Kato Katz showed that the carbon and cassette had specificities of 70%, 89% and 75% with high sensitivity of 96%, 71% and 96%, respectively. While Kato Katz was 74% sensitive and 95% specific (Kittur et al., 2016). The result in both CCA tests reflected stool egg burden and their performance was not affected by presence of STH showing that urine can be used for *S. mansoni* infections.

Ultrasonographic examination of the abdomen has been used to assess extent of destruction on the internal organs like the liver, spleen and kidneys and bladder. In chronic untreated *S. mansoni* infections, portal fibrosis is a common finding in endemic areas. This periportal fibrosis can be seen on ultrasonography, computed tomography, or magnetic resonance imaging and is characteristic of schistosomiasis. Hepatocellular synthetic function is preserved until the very late stages of disease. Lobular architecture is retained, and nodular regenerative hyperplasia does not occur. Ultrasonography, in addition to clinical examination, is used to detect and quantify hepatosplenic disease (Ross et al., 2001, Mutengo et al., 2014) based on the WHO. The prevalence of fibrosis increases with increasing age and the milder form of portal

fibrosis is normally seen in younger age groups as was seen in the Zambian study (Mutengo et al., 2014).

2.4.7 Overview of schistosomiasis control initiatives

There are technical terms that we always hear of in public health such as prevention and control, elimination, and eradication; and surveillance, monitoring and evaluation. All interventions are done towards achieving disease eradication. Schistosomiasis is a public health problem in several parts of the world and still requires a lot of concerted interventions to control and eliminate before it is considered for eradication. The control strategies have evolved from just snail control to chemotherapy and this because of availabilities of newer and safer drug such as niridazole, metrifonate, oxamniquine and praziquantel given as a single oral dose. However, treatment with praziquantel has been the mainstay of schistosomiasis. Its single-dose oral administration is cost effective and is being used for large-scale preventive chemotherapy (Gabrielli et al., 2011). Oxamniquine is the only alternative to praziquantel for *S. mansoni* infection but has limited availability (Ross et al., 2001).

Over the past 50 years the challenge of schistosomiasis control has persisted as a complex dilemma for health policy makers and triggered debates as to whether it has any significance to public health and whether it has priority for control. Light worm burden of schistosomiasis was thought remain asymptomatic, implying they do not provoke disease, nor do they specifically require medical care. For more than 440 million people with bilharziasis around the world, this is caused by past and present infection and if left untreated (World Health Organization, 2013f), a schistosome worm will persist an average of two to five years and with the dynamics of infection and reinfection people at risk will experience active Schistosoma infection for an average of 15 or more years (King et al., 2011, Stothard et al., 2017a)

With increase in the praziquantel donations and improved access, countries have to take this opportunity, in all 52 countries that are endemic and requiring preventive chemotherapy. Approximately 218.2 million people were in need of preventive chemotherapy globally in 2015 of which school aged children represented 118.4 million. Globally in 2015, a total of 74.3 million people received preventive chemotherapy for schistosomiasis and coverage for school-aged children increased

significantly in 2015 (44.9%) compared with 2008 (14%), representing more than two-thirds of the 2020 target of 75% (World Health Organization, 2012a, World Health Organization, 2013f, World Health Organization, 2013g).

This is the trajectory that should be followed if we are to control, eliminate and eradicate schistosomiasis. Nevertheless, in Africa 28 (69.5%) of the endemic countries conducted MDA in 2015 with only 53.7% covering all endemic areas(World Health Organization, 2017b) . Progress in the control of schistosomiasis has always been reviewed in the 2001-2011 report, and a WHO strategic plan 2012-2020 with a vision of "a world free of schistosomiasis" and goals to control morbidity and eliminate schistosomiasis as a public health problem by 2020 and 2025 respectively. This therefore has called for scaling-up of interventions towards transmission interruption and to ensure adequate and constant supply of praziquantel and resources to meet the demand (World Health Organization, 2013f).

Current large-scale drug treatments can significantly reduce schistosome infection burden in participating communities though parasite transmission may, nevertheless, continue unaffected because of several different factors that influence the life cycle. Alternative and complementary strategies need to be considered. There is an urgent need to step-up praziquantel treatment in Africa to reach the goal of treating at least 75% of school aged children in all endemic countries (Gabrielli et al., 2011). Pre-school age children with schistosomiasis are excluded from mass treatment but can be treated in health facilities. However, administration of treatment in the African settings is problematic because of limited diagnostic capacity and lack of an appropriate paediatric formulation of praziquantel but in some instances the care providers crash praziquantel and mix with juice or syrup to reduce the bitter taste and make it more palatable (Stothard et al., 2013a).

The most important aspect in SCH control is having the evidence or baseline data that SCH is endemic in a particular area. This is What will determine the treatment strategies to be implemented. In initial mapping studies, predictions were largely based either on simple threshold analysis or traditional regression modelling to predict the presence or absence of infection. This was based on the 2-5 schools that would be sampled in a district and other areas the province or region posing a big challenge considering the focalisation of schistosomiasis. Due to the focal nature

of schistosomiasis, up to 53% simulated surveys involving 2–5 schools per district failed to detect schistosomiasis in low endemicity areas (1–10% prevalence). Increasing the number of schools surveyed per district improved treatment class assignment far more than increasing the number of children sampled per school (Knowles et al., 2017). In the WHO strategic plan 2012-2020, mapping is a key feature towards the elimination of schistosomiasis. This gives good basis for chemotherapy and indicators for monitoring and evaluating the programme. The data on treatment are collected to measure the progress being made towards achieving the targets set by World Health Assembly resolutions to reach >75% all school-aged children who are at risk of morbidity from schistosomiasis (World Health Organization, 2001, World Health Organization, 2012a, World Health Organization, 2013f).

To make the complexity of the programme much easier to understand, a roadmap of schistosomiasis control has been developed with targets that also provide reductions in their impact to levels at which they are no longer considered public-health problems. This can be assessed as implementation control efforts on mortality, morbidity and transmission (World Health Organization, 2012a, World Health Organization, 2013f). Recent modelling indicates that preventive chemotherapy for schoolchildren may break schistosomiasis transmission cycle in specific epidemiological settings, to prevalence of less than 10% in school-based programmes, especially in countries with strong health systems and drug-delivery mechanisms (Campbell et al., 2017). WHO reports that schistosomiasis will be eliminated in the Caribbean, the Eastern Mediterranean, Indonesia, and the Mekong River basin by 2015 (Chitsulo et al., 2000). This will be a very big achievement that other countries would and should learn from. Interruption of transmission remains to be validated in 19 countries globally, including Algeria, Mauritius and Tunisia from the African region which is also very encouraging to see success in the region (Chitsulo et al., 2000). With these successes that are being recorded, a resolution (World Health Organization, 2012b) at the sixty-fifth World Health Assembly, elimination of schistosomiasis, was passed to attach importance to prevention and control of schistosomiasis, to analyse and develop applicable plans with progressive targets, to intensify control interventions and to strengthen surveillance as it has now been seen that schistosomiasis can be eliminated. This has further led to the

development of the roadmap for nine years (2012-2020) outlined in the WHO report on sustaining the drive to overcome the global impact of neglected tropical diseases (World Health Organization, 2012a) as shown in Table 2.3

Table 2-3 Roadmap for schistosomiasis control and elimination.

Guide from WHO goal, interventions, targets and estimated progress for countries depending on the stage of implementation and endemicity status for SCH morbidity control, and elimination (World Health Organization, 2012a)

Group	**Countries eligible for control of morbidity**	**Countries eligible for elimination as a public health problem**	**Countries eligible for elimination (interruption of transmission)**	**VERIFICATION**	**Countries that have achieved elimination**
Goal	Control morbidity	Eliminate SCH as a public health problem	Eliminate SCH (interrupt transmission)		Implement post elimination surveillance
Recommended interventions	Preventive chemotherapy Complementary health interventions where possible	Adjusted preventive chemotherapy Complementary health interventions strongly recommended	Intensified preventive chemotherapy in residual areas of transmission Complementary public health interventions considered essential		Surveillance t detect and respond to resurgence of transmission and to prevent reintroduction
Targets	100% geographical coverage and ≥75% national coverage Prevalence of heavy intensity infection <5% access sentinel sites	Prevalence of heavy-intensity infection <1% in all sentinel sites	Reduce incidence of infection to zero		Incidence of infection remains zero (no cases)
Estimate progress from one group to the next	Up to 5-10 years from joining the group	Up to 3-6 years from joining the group	Up to 5 years from joining the group		To continue until all countries have interrupted transmission

2.4.8 Interrupting transmission

The overall goal for combating schistosomiasis is to prevent and control its morbidity and transmission. To monitor this, a set of indicators looking at prevalence and parasitic intensity are used (Ross et al., 2001). The latter is a proxy of schistosomiasis

attributable morbidity were the number of eggs in the tissues produced by adult worms (worm burden or egg load) affecting an individual is directly linked to the damage they cause. Prevalence rises with increasing intensity and is accompanied by an increased risk of developing morbidity and disease (pathology of the urogenital tract; hepatomegaly and hepatosplenomegaly). However, severe pathology can occur in light infections and does not develop in all heavy infections (Sturrock, 2001). The simplest approach is mass chemotherapy, treating everybody in a known, endemic community with a curative dose of praziquantel. Therefore, it is advisable to review the indicators every three to five years (World Health Organization, 2013f) to assess impact of interventions. One other key indicator that contributes to the success of a programme is the treatment coverage (Gabrielli et al., 2011). Once intervention has commenced, 75% of the eligible population should receive treatment for five years or more in addition to environmental manipulation or modification to control transmission and possibly eliminate schistosomiasis (Chitsulo et al., 2000). This is What will progressively reduce the prevalence and the intensity of infection. Only a small proportion of less than 5% could have heavy-worm intensity as this is a threshold that would achieve morbidity control in the targeted population. This is supported by the findings of Michael et al in 2007 who used mathematical modelling to estimate reductions in the rate of *Schistosoma mansoni* reinfection following annual mass drug administration with praziquantel in Uganda over four years which showed that MDA achieved substantial and statistically significant reductions in the force of infection following one round of MDA with a significant ancillary impact of reducing transmission in the community and may provide health benefits to those who do not receive treatment (Kabatereine et al., 2011, Stothard et al., 2017b, Stothard et al., 2011b).

2.4.9 Brief history of schistosomiasis in Zambia

Earlier publications by Buckley indicated that human infections with schistosomes are widespread in Zambia (Buckley, 1946). Despite being classified as a moderate endemic country for these infections, and a recent modelling study suggesting an average schistosomiasis prevalence of 26% among school aged children (Chimbari et al., 2003), there is a lack of published data on the present occurrence and distribution of these infections. Buckley in 1946 reported on bilharzia of both vesicular (urinary) and intestinal forms as being widespread on an increasing

frequency but generally maintaining uneven distribution with very little knowledge known on the its economic importance (Buckley, 1946). There were challenges in the accurate diagnosis of schistosomiasis is the inverse relationship of the age of the host and the excretion of ova, had not yet been satisfactorily accounted for; but until such time as the true explanation shall be forthcoming, the validity of microscopical diagnosis of the infection in adults was an open to doubt. Several possible explanations include: 1. Acquired partial immunity. 2. Reduced opportunities of becoming infected, owing to habit, in adults. 3. Reduced egg-laying. Additionally, the incidence of *S. haematobium* was higher in children than adults and the two findings were statistically significant (Buckley, 1946) even in other locations where later studies were conducted.

Later studies conducted in Luapula Province, in the second quarter of the mid-20th Century, showed *S. haematobium* prevalence to be higher than *S. mansoni* and was evenly distributed throughout the province unlike *S. mansoni*. The prevalence of *S. hematobium* infection was (14-40%) and that for *S. mansoni* to range from (0-7%), in the Northern and Luapula Provinces. Mainly affected areas were around Lakes such as Bangweulu in the north which had prevalence rates of (3-35%) for *S. haematobium* and (2-6%) for *S. mansoni* and Kariba in the south (Chimbari et al., 2003). In 2005 Clements et al described *S. mansoni* to be more restricted in its distribution with high prevalence in schools located in small pockets in Siavonga, Sinazongwe and Itezhi-tezhi districts (Clements, 2005). The lack of recognition of schistosomiasis and STH infections as public health problems and contributors to morbidity is as true in Zambia as in the rest of Africa. The Zambia Bilharzia Control Programme (ZBCP) conducted cross-sectional surveys in which blood-in-urine questionnaires, parasitological data and Geographical Positioning Systems (GPS) readings were collected in more than 80 schools to assess prevalence between 2005 and 2007 with the support of SCI. The surveys were not countrywide but in a few selected provinces and districts. Risk maps were developed to identify areas at high risk of infection for schistosomiasis and STH and where control should therefore be targeted. The maps were the latest to confirm that *S. haematobium* is prevalent extensively and that *S. mansoni* more focalised in Zambia. In 2009 the first NTD Plan of Action 2009-2015 was developed based on the predictive maps (Clements,

2005). However, the disease distribution for effective implementation of interventions was inadequate due to the sample size and study sites or locations.

Despite the pre-existing estimates of schistosomiasis frequency, there is little data documenting the extent of infection at subdistrict level and a purely peri-urban environment, especially one not in close proximity to a permanent water body. A cross-sectional study conducted in a peri-urban environment in Lusaka district in a township called Ngombe during the dry season showed a prevalence of *S. haematobium* at 20.72% in school aged children which was very high for an exclusively peri-urban setting without large or major water bodies (Agnew-Blais et al., 2010). The question that arise is why *S. haematobium* is high in such an environment? Could it be infections related to seasonal fluctuations especially in rainy season or geographic variation with respect to proximity of water bodies and water-related community practices that had a significant effect on prevalence rates and patterns? Further data are needed to understand the relationship of *S. haematobium* infection to peri-urban geography and community water practices. Given their hybridization of urban and rural models of water supply infrastructure, Ng'ombe and other similar compounds represent potentially informative environments in which to study these relationships and malacological surveys to determine the location of infected snail vectors.

2.5 Soil-transmitted helminthiasis

2.5.1 General information

This third group of NTDs called soil-transmitted helminths (STH) are amongst the most prevalent parasitic diseases in sub-Saharan Africa affecting more than 1 billion people in socio-economically depressed communities. They are mainly caused by hookworm (*Ancylostoma duodenale* and *Necator americanus*), *Ascaris lumbriocides* and *Trichuris trichiura* (Bethony et al., 2006). They are transmitted by eggs present in human faeces which in turn contaminates soil mainly in areas with poor sanitation. The symptoms of STH are non-specific and only become evident when the infection is severe. The infections aggravate malnutrition and amplify rates of anaemia with resultant stunted growth and poor cognitive development (Bethony et al., 2006). Affected children fail to go to school and this subsequently contribute to the vicious cycle of poverty. For the control of these diseases, WHO recommends

periodic administration of anti-helminthic such as albendazole or mebendazole, as a public health intervention (Gabrielli et al., 2011). In 2016, WHO estimated that 836.2 million (267.5 million pre-SAC and 568.7 million SAC) required annual treatments and 633.2 million received preventive chemotherapy for soil-transmitted corresponding to 59.7% global coverage well above the 50% global coverage target set for that year (World Health Organization, 2017b).

2.5.2 The burden of soil-transmitted helminthiasis

Soil-transmitted Helminths are widespread in most poverty-stricken areas in the developing world. They are well distributed in the tropical and subtropical areas (Figure 2.6) and temperate zones during warmer months were there is inadequate water, sanitation and hygiene. They affect more than a billion people globally of whom 300 million suffer severe morbidity and sometimes the species occur concurrently in the same community (World Health Organization, 2017b).

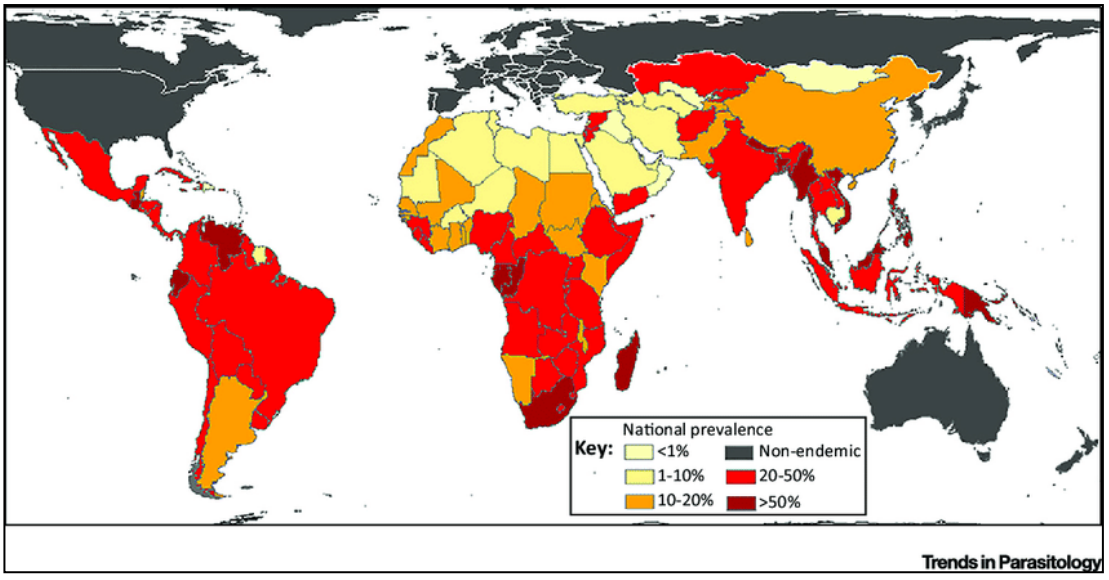


Figure 2-6 Map showing the global distribution of soil transmitted helminthiasis

Most of Sub-Saharan Africa is highly endemic for STH. Zambia has moderate endemicity. More than 50% prevalence in South Africa and Madagascar (Pullan et al., 2014)

Table 2-4 Global estimates of cases with soil-transmitted helminthiasis by type in WHO Region

Africa shows a high level of prevalence for all the species by age groups (Montresor et al., 2020, Pullan et al., 2014, World Health Organization, 2017b).

Type of infection and WHO Region	Estimated number of STH infections in millions				
	0-4	**5-9**	**10-14**	**≥15**	**Total**
ASCARIASIS					
African	28	28	25	92	173
Americas	8	10	10	56	84
East Mediterranean	3	3	3	14	23
South East Asia	28	33	30	145	237
Western Pacific	55	69	76	505	705
TOTAL	122	143	144	812	1222
TRICHURIASIS					
African	26	27	23	66	162
Americas	10	12	12	86	100
East Mediterranean	1	1	1	4	7
South East Asia	18	20	19	90	147
Western Pacific	30	38	41	268	379
TOTAL	85	98	96	514	795
Hookworm disease					
African	9	18	29	142	198
Americas	1	3	5	41	50
East Mediterranean	0	1	1	8	10
South East Asia	4	10	16	100	130
Western Pacific	7	18	34	293	352
TOTAL	21	50	85	584	740

2.5.3 The lifecycle of soil-transmitted helminths

Each species has different life history pattern, but each has high host specificity for humans. Nevertheless, they all mature and undergo sexual reproduction in the intestinal tract. Soil-transmitted helminths are called so because their transmission depends on contamination of the environment or soil with fertile eggs passed in faeces of infected humans. In most parts of the world, transmission occurs without seasonal disruptions. The eggs are not infective until the zygotes they contain undergo embryonation which requires warmth, shade and moisture. When these eggs are ingested, or inhaled infection occurs (Montresor, 1998).

Soil-transmitted helminths live in the intestine and their eggs are passed in the faeces of infected persons. Infected people who defecate on open ground (near bushes, in a garden, or field) in areas where there is no latrine system or if the faeces are used as fertilizer the soil and water around the village or community becomes

contaminated with faeces containing these eggs. The persistence of STH is closely linked to contamination of the environment with the faeces of infected people (Montresor, 1998, Hotez et al., 2006a). The eggs for *Ascaris* and *Trichuris* mature in soil and become infective and people are infected when these eggs are ingested. This can happen when hands or fingers that are contaminated are put in the mouth or by consuming vegetables and fruits that have not been carefully cooked, washed or peeled. The ingested Trichuris eggs release larvae moult which travel to the colon where they burrow into the epithelia and develop into adult whipworms within about 12 weeks. *Ascaris* larvae penetrate the intestinal mucosa and after an extraintestinal migration enter the liver then the lungs, before passing over the epiglottis to re-enter the gastrointestinal tract and develop into egg-laying adult worms about 9–11 weeks after egg ingestion (Bethony et al., 2006). On the other hand, hookworm eggs are not infective but the mature larvae from the immature larvae released after the eggs hatch in soil that can penetrate the skin of humans. *N. americanus* and *A. duodenale* hookworm larvae moult twice to become infective third-stage larvae, which are non-feeding but motile organisms that seek out higher ground to improve the chance of contact with human skin. Hookworm infection is transmitted primarily by walking barefoot on contaminated soil. After skin penetration, they enter subcutaneous venules and lymphatic vessels to access afferent circulation. Ultimately, the larvae become trapped in pulmonary capillaries, enter the lungs, pass over the epiglottis, and migrate into the gastrointestinal tract. They take 5–9 weeks from skin penetration to development of egg-laying adults. *A. duodenale* larvae are also infective when ingested (Bethony et al., 2006, Hotez et al., 2006a). Figure 2.7 describes the life cycle for STH in more detail.

The mature worms mate and produce eggs that are excreted through faeces and the cycle goes on (Montresor et al., 2015, Hotez et al., 2006a).

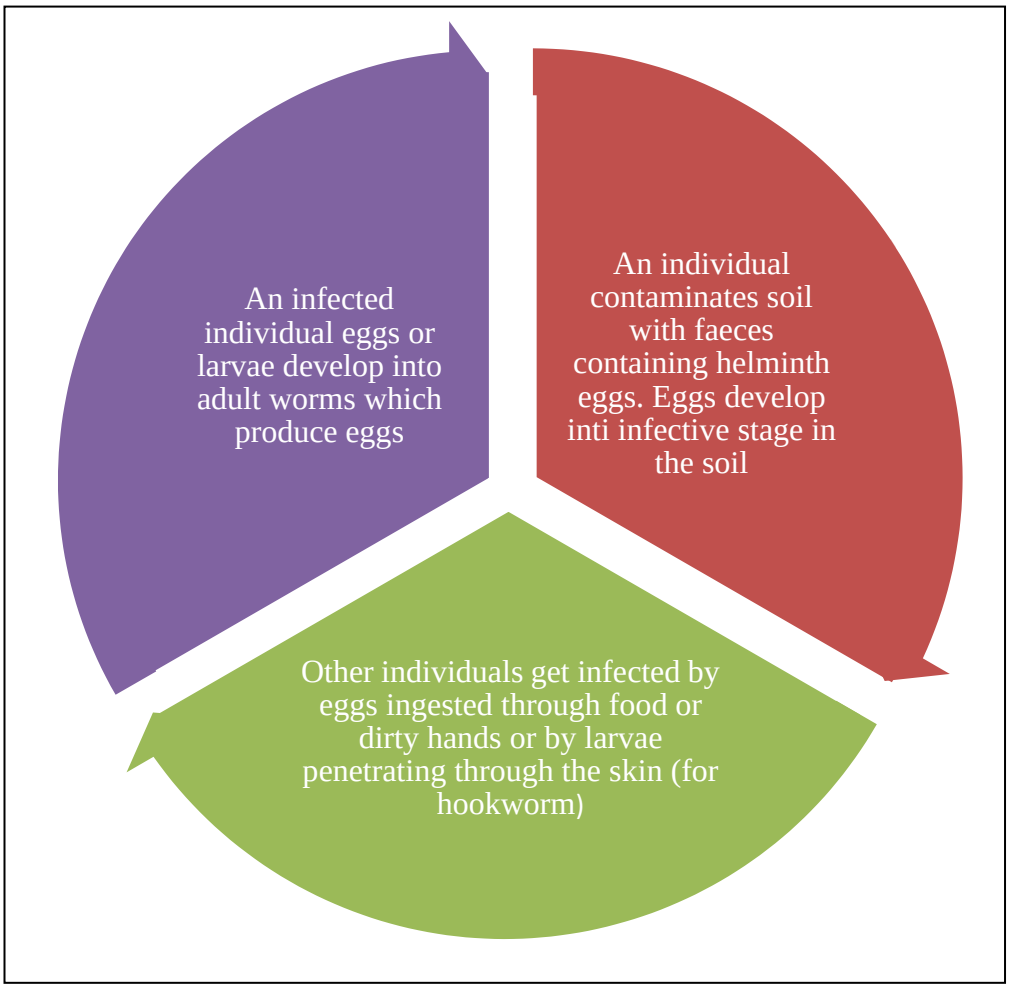


Figure 2-7 Life cycle for STH

Three main stages of STH lifecycle of conatamination of the soil, ingestion of eggs through food and dirty hands and an infected individual eggs become adult worms and produce eggs which further contaminates the soil (Hotez et al., 2006a)

2.5.4 Clinical manifestation and treatment

People with light soil-transmitted helminth infections (*A. lumbricoides* - 1-4,999 epg; *T. trichiura*-1- 999 epg; and hookworm- 1-1,999 epg) as shown in Table 2.4 below usually have no symptoms. Heavy infections (*A. lumbricoides* >50,000 epg; *T. trichiura* >10,000 epg; and hookworm >4,000 epg) (Montresor, 1998) can cause a range of health problems, including abdominal pain, diarrhoea, blood and protein loss, rectal prolapse, and physical and cognitive growth retardation. For hookworm infections the degree of severity varies not only according to the number of worms present but also to the age, species and nutritional intake of iron. Fixed categories were not defined by the 1987 WHO Expert Committee. The above

categories are given according to the faecal loss of haemoglobin found by (Montresor et al., 2003). In African children infected mainly with *N. americanus*, light intensity infections are related to a loss of less than 2 mg of haemoglobin per gram of faeces and heavy intensity infections correspond to a loss of more than 5 mg of haemoglobin per gram of faeces. *A. duodenale* causes greater blood loss than does infection with *N. americanus*, the degree of iron-deficiency anaemia induced by hookworms depends on the species. Soil-transmitted helminth infections are treatable with medication prescribed by your health care provider (Hotez et al., 2006a).

2.5.5 Diagnosis of soil-transmitted helminths

Reliable, sensitive and practical diagnostic tests are available to detect eggs in stool and immunological examination. Diagnosis play an important role in guiding the deployment of existing STH program resources and the implementation and evaluation of STH intervention strategies such as mapping, assessing impact of interventions and surveillance (Montresor, 1998). Like SCH, STH eggs are detected in stool using microscopy and the Kato Katz technique. Depending on the number of the eggs present per gram of stool, the parasitic intensity can be classified as light intensity, moderate or heavy intensity. The number of eggs according to the species is shown in Table 2.5 below. The presentation of the results in classes of intensity allows the proportion of individuals suffering severe consequences to be quantified. Since the first objective of any control programme is the reduction of the proportion of highly infected individuals, this indicator is extremely important for the selection of the control measures, and in monitoring the results of the programme (Table 2.5). However, the sensitivity of Kato Katz ranges between 74 and 95%. However, there are more sensitive tests like FLOTAC that can be used to determine the disease distribution or presence of STH (Glinz et al., 2010). To provide a robust geographical assessment of the various tests by comparing the sensitivities and the quantitative performance of the most commonly used copro-microscopic diagnostic methods for soil-transmitted helminths, (Campbell et al., 2016) conducted a meta-analysis of for six commonly used diagnostic tools in the field and laboratory namely Kato-Katz, direct microscopy, formyl-ether concentration, McMaster, FLOTAC and Mini-FLOTAC (Nikolay et al., 2014). Sensitivity estimates are low with direct microscopy (42.8%) and the most sensitive is FLOTAC (92.7%).

Studies have shown that sensitivity of these tests increases with the intensity of the infection and decrease with low intensity (Montresor, 1998). Where the intensity is low sensitivity drops. The widely used double slide Kato-Katz method with a sensitivity of 74-95% for the three soil-transmitted helminth species at high infection intensity drops to 53-80% in low intensity settings and it has been observed the drop is very significant with hookworm and *Ascaris*. FLOTAC has high sensitivity in both high and low intensities while Kato Katz is comparable with mini-FLOTAC.

Table 2-5 Parasitic intensity and grading for STH species:

The thresholds proposed for use by a WHO Expert Committee in 1987 for the classes of intensity for each helminth in stools (Montresor, 1998).

helminth	light intensity infections	moderate intensity infections	heavy intensity infections
A. lumbricoides	1-4,999 epg	5,000-49,999 epg	>50,000 epg
T. Trichiura	1-999 epg	1,000-9,999 epg	>10,000 epg
hookworms	1-1,999 epg	2,000-3,999 epg	>4,000 epg
epg=eggs per gram of feces			

Examination of stool using Kato-Katz should be done immediately after the slides are prepared. This is to ensure the eggs are detected before they disintegrate due to the clearing effect of glycerol (Montresor, 1998). Even though microscopic examination of stool samples is commonly used to detect infections with gastrointestinal helminths it is not sensitive and may result in misdiagnosis leading to delayed or inadequate treatment. However, even though the commercial antibody detection tests are available for some STH infections, they are generally not sensitive or specific and are not able to differentiate current and past infections (Basuni et al., 2011). Further, specific antibody tests to STH detection have not been studied at length and therefore, has not been considered necessary for diagnostic purposes, and relatively little work has been undertaken to develop and standardize serological assays for hookworm infection, ascariasis or trichuriasis except for strongyloidiasis. In terms of antigen detection some work has been done on zoonotic hookworms demonstrating the presence of coproantigen in faeces. However, no assay has reached a mature stage of development. Assays providing promising ability to undertake multiplex and quantitative assessment of STH have been undertaken for molecular diagnosis using PCR-based diagnosis of hookworm infection has been

developed and subject to pilot testing in human populations (Basuni et al., 2011). A multiplex PCR assay has been described and shows promise for quantifying egg counts for hookworm infection and ascariasis. Adult worms may occasionally be coughed up or passed in stool or vomit.

2.5.6 Overview of control initiatives for soil-transmitted helminths

Most endemic areas of STH are co-endemic with either SCH or LF requiring integration of interventions (Molyneux et al., 2005) for NTDs. With this growing emphasis on, and need for, integrated control of neglected tropical diseases, control of five neglected tropical diseases (STH, trachoma, lymphatic filariasis, schistosomiasis and onchocerciasis) can be attained in a cost-effective manner through administration of just four drugs (albendazole or mebendazole, azithromycin, praziquantel and ivermectin) (Engels and Zhou, 2020, Gabrielli et al., 2011, Molyneux et al., 2005) improving the delivery of NTD control programs in resource-poor regions such as sub-Saharan Africa, where millions remain at risk of these diseases. Control interventions are further enhanced through targeting of co-endemic areas with emphasis on geospatial tools (geographical information systems, remote sensing and spatial statistics) (Hotez et al., 2006a, Pullan et al., 2014). In a cross-sectional epidemiological survey carried out in 57 schools of western Côte d'Ivoire, 4000 children were examined for *S. mansoni*, soil-transmitted helminths and malaria parasitemia. Focusing on *S. mansoni* and hookworm, it was found that 19% of the children were co-infected, whereas 24% were infected with either *S. mansoni* or hookworm. Risk maps of mono-infections and co-infection were produced using Bayesian-based geostatistical models that included demographic, environmental and socio-economic covariates (Utzinger et al., 2009, Raso et al., 2006). A common understanding of the concept of integration can help guide futurediscussions about the opportunities and challenges for integration among NTDcontrol programs.

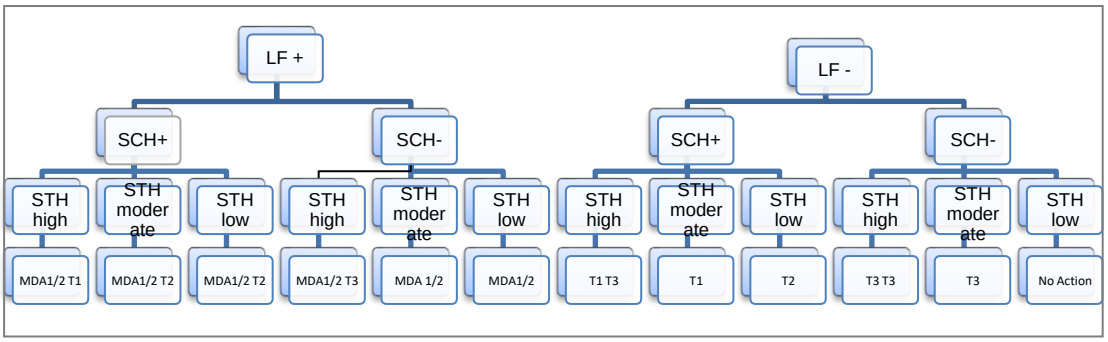
The integration of NTD control programs offers the potential for there is a need to accelerate the implementation of integrated NTD control activities including preventive chemotherapy, but they also must be evaluated in a systematic manner. It is believed that this framework can help understand how to best create linkages

among these programs and how to deliver much needed services to affected communities in more efficient and effective ways (Gabrielli et al., 2011).

Preventive chemotherapy, a strategy first used for delivering anthelminthic medicines through a population-based approach, focuses at optimising the use of single administration of drugs targeted simultaneously at more than one form of helminthiasis as one of the efforts described in the WHO54.19 on SCH and STH infections (World Health Organization, 2001). The aim and rationale of this is to avert the widespread morbidity that invariably accompanies helminth and sometimes may lead to death. Early and regular administration of the anthelminthic drugs recommended by WHO reduces the occurrence, extent, severity and long-term consequences of morbidity, and in certain epidemiological conditions contributes to sustained reduction of transmission. It requires the delivery of quality good drugs either alone or in combination to as many people in need as possible at regular intervals throughout their lives (Gabrielli et al., 2011). The list of medicines and the NTD they treat is shown in Table2-6 and the strategy used is described in Figure 2.8.

Table 2-6 WHO recommended anthelminthic drugs for use in preventive chemotherapy (Gabrielli et al., 2011)

Disease	ALB	MBD	DEC	IVM	PZQ	LEV	PYR
Ascariasis	√	√		√		√	√
Hookworms	√	√				√	√
Lymphatic filariasis	√		√	√			
Schistosomiasis					√		
Trichuriasis	√	√		√		√	√



Key: MDA1: IVM+ALB; MDA2: DEC+ALB; T1: ALB+PZQ or MBD+PZQ; T2: PZQ; T3: ALB orMBD

Figure 2-8 Coordinated preventive chemotherapy strategy for the three PC NTDs

The flow chart of the implementation of LF, SCH and STH based on endemicity status (Gabrielli et al., 2011).

2.5.7 Brief history of soil-transmitted helminths in Zambia

Soil-transmitted helminths infections have been known to be indigenous in Zambia of which *A. lumbricoides* infections were thought to be widespread and probably of universal occurrence in the Bangweulu swamps. Less frequently recorded was *Trichuris trichiura.* In 1946, hookworm infections were found to be universal as they were present at each location of the surveys conducted across the nation (Buckley, 1946). The climatic factor here involved must have been temperature since according to available records, there was no correlation between rainfall and altitude. ANational Nutrition Survey carried out in 1977 indicated that overall hookworm prevalence was 48.6%, with a range of 11.4–77.1% (Ministry of Health, 2007). No interventions were put in place despite all these findings until a National Plan of Action for schistosomiasis control in which the STH programme was incorporated, was compiled by the Ministry of Health in 1998. However, this was not implementeduntil the School Health and Nutrition (SHN) programme was created in 2000 that any drug administration for schistosomiasis and STH began. The SHN programme was as a result of collaboration between the Ministries of Education and Health, withsupport from the United States Agency for International Development. By 2005, SHN had delivered their messages and drugs (including PZQ and ALB) to 243 200 school children but the drawback was that the programme only targeted governmentschools. Recognising this huge gap, Zambia Bilharzia Control Programme (ZBCP) was formed to bridge the gap of coverage to school-aged children in community schools and communities in high-risk areas (Kabatereine et al., 2006). The ZBCP implemented interventions in southern and Eastern Provinces the two provinces where mapping surveys were conducted, and this was done through trained teachers and community health workers (Clements, 2005). It was not until 2010 when the ministry introduced an integrated NTD control programme under which the mapping exercise that is being reported on was conducted.

Chapter 3 Mapping the decline in lymphatic filariasis and the potential impact of vector control

3.1 Abstract

Background: Lymphatic filariasis (LF) also known as elephantiasis is widely spread in Zambia at low prevalence rates and is caused by *Wulcheria bancrofti.* The parasite is transmitted by the anopheles' mosquitoes, a vector for *Plasmodium falciparum* in Zambia. LF in Zambia is targeted for elimination by mass drug administration (MDA) of albendazole and diethylcarbamazine citrate (DEC) to at-risk populations. LF mapping data collected between 2003–2005 and 2009–2011 to LF sentinel site prevalence data collected between 2012 and 2014, indicated a decline in prevalence over the years before any MDA. Whilst a causal relationship between LF prevalence and ITN coverage cannot be proved, the assumption is the scale-up of ITNs helped to control Anopheles mosquito populations, which have in turn impacted on LF transmission significantly before the scale-up of MDA.

Methodology: From the results of a descriptive cross-sectional study of LF in 72 districts of Zambia, I examined the putative association between decreasing LF prevalence and increasing coverage of insecticide-treated mosquito nets (ITNs) for malaria vector control. ITN coverage was quantified and compared for each site in relation to the dynamics of LF. A Spearman's Correlation and linear modelling in R was performed to demonstrate the association.

Principal findings: A significant decrease in LF prevalence from the years 2003–2005 (11.5% CI95 6.6; 16.4) to 2012–2014 (0.6% CI95 0.03; 1.1); a significant scale-up of ITNs across the country from 0.2% (CI95 0.0; 0.3) to 76.1% (CI95 71.4; 80.7), respectively. ITN coverage was a better predictor of LF prevalence than year alone with a significant Spearman's correlation of -.462 at the 0.01 level (2-tailed), R^2= 0.1878 (year alone) and 0.2837 (year and ITN coverage).

Conclusion: The putative synergy of LF prevalence with vector control has provided evidence that helped to put Zambia on track to meet national and global goals of LF elimination by 2020.

3.2 Introduction

LF is widely endemic in Zambia but with low prevalence. Overall prevalence rates were estimated at 7.4% in 2011 from more than 10,000 sampled individuals across 108 sites in all regions of the country by rapid circulating filarial antigen (CFA; a marker of the *Wuchereria bancrofti* adult worm infection) BinaxNOW Filariasis immunochromatographic test (ICT) card (Mwase et al., 2014). The initial mapping started in 2003 and 2005 at 42 sites across 14 districts thought to be endemic for LF. The prevalence ranged from 1.0% –53.9% with the highest found in Lusaka and Western Provinces. Mapping in the remaining 58 districts was conducted at 65 sites in 2009 and 2010, with one site in early 2011. The prevalence ranged from 0–20.8% with the highest in Luapula and Northern Provinces. This endemicity data helped the National LF Programme plan its elimination strategy with an estimated 11 million people requiring treatment. However, the scale-up of programmatic activities was slow to start in Zambia, as unlike many countries in Africa, it did not benefit from the African Programme for Onchocerciasis Control (APOC) that distributed free ivermectin to countries through the established and well-trained community drug distributor (CDD) networks (World Health Organization, 2011).

The Global Programme to Eliminate Lymphatic Filariasis (GPELF) aims to eliminate LF by 2020 by interrupting LF transmission through MDA and controlling morbidity (Ottesen, 2000, Ottesen et al., 2008). In Zambia, as onchocerciasis is not endemic, the use of the drug combination of diethylcarbamazine citrate and albendazole for MDA activities is recommended (Gabrielli et al., 2011). Albendazole has been donated to all countries LF Programmes from GlaxoSmithKline (GSK) under APOC, however, DEC had only recently become available for Zambia as a donated drug by Eisai Co., Ltd (World Health Organization, 2016). In 2012 and 2014, Zambia conducted a national baseline sentinel site survey across 40 selected sites prior to the start of implementation activities so that impact could be measured over time. In 2015, Zambia successfully scaled up MDA to reach full geographic coverage with very high population compliance rates as part of its strategy to interrupt transmission, making it the largest and most successful distribution of DEC for LF in Africa in history (World Health Organization, 2016).

The general information about mosquitoes species in Zambia in association with LF is very limited. However, the major vector for malaria is the anopheles

mosquito which is found in all the regions in varying prevalence rates (Mwase et al., 2014, Shawa et al., 2013). LF is transmitted by some anopheline species and the precise incrimination is limited. It is known that in many regions in Africa the LF *Anopheles* vectors are the same, or similar, to those of malaria, which are found across all regions of Zambia at varying distributions and species compositions (Coleman et al., 2017). For example, *An. funestus* and *An. gambiae* are the predominant species in the wetter Eastern, Luapula, Northern and Lusaka provinces while *An. arabiensis* is more dominant in the drier southern region (Chanda et al., 2011, Masaninga et al., 2013, Kamuliwo et al., 2013). A study conducted in Luangwa district in 2011, associated *An. funestus* and *An. gambiae* with LF transmission, however, transmission was not directly confirmed (Shawa et al., 2013). Overall LF prevalence was found to be low (8.6%) and indicated a marked decline from prevalence measured in 2003 (33.3%) (Mwase et al., 2014). Therefore, the most common and more probable transmitter of LF in Zambia is the anopheles species, thus, the reduction in prevalence that was noted can be attributed to the concurrent scale up vector control in the area.

Zambia's achievements in scaling-up interventions are distinctive as it has made tremendous strides over the past decade with very high coverage of vector control for malaria (Chanda et al., 2013). In line with the global trends to improve efforts in malaria control Zambia has put in measures to mitigate malaria transmission including vector control using insecticide-treated mosquito nets (Chanda et al., 2012a, Chanda et al., 2012b, Chizema-Kawesha et al., 2010). An example of how the net looks like and its utilization is as shown in Figure 3-1, which are distributed at antenatal and child clinics, equity programme and community mass distributions had reached over 60% at household level in 2008 with the aim of attaining 100% coverage (Chanda et al., 2011). Between 2010 and 2012 over 7 million new long-lasting insecticide nets (LLINs) were delivered with up to 94% of the population potentially protected from malaria infection. The 2013–2014 Demographic and Health Survey (DHS) reported that around seven in 10 households (68%) owned an ITN, with Southern (79.5%), Eastern (77.1%) and Western (76.5%) Provinces reporting the highest provincial ITN coverage.

Figure 3-1 A picture showing the utilisation of an ITN/LLIN

A mother and child sleeping under a mosquito net as way of protecting themselves from night biting mosquitoes that carry the malaria parasite .

With sound policies attracting partners and resources funding for malaria control is high with mounting evidence of health impact from malaria control in the country. Malaria parasite prevalence in the under-five year old reduced by 50% over a two-year period (21.8% in 2006 to 10.4% in 2008). A further 67% reduction in parasitic prevalence in infants was noted (Chizema-Kawesha et al., 2010) with an incremental overall reduction in infection transmission in those who use a combination of IRS and ITNs (Chanda et al., 2011). This is also reflected in the World Malaria Report of 2013 where malaria hospital admission and death have dramatically fallen between 2001 and 2012. Given that malaria and LF are transmitted by the same or similar *Anopheles* species is likely that the well-established vector control programme had also impacted on LF transmission over the decade (2003 - 2013) before the scale up on MDA in 2015.

3.3 Overall Aims and Specific Objectives

The overall aims of this chapter were to quantify the changes in LF prevalence over time and examine the association and potential impact of vector control for malaria on the transmission. Specifically, the study objectives are divided into LF prevalence and vector control.

Objectives: LF prevalence

i) describe the distribution of LF prevalence from mapping surveys conducted between 2003-2011
ii) conduct baseline sentinel site surveys between 2012 – 2014 in preparation for scale up of MDA
iii) determine changes in distribution patterns of LF prevalence between 2003-2014

Vector control

iv) determine changes in distribution patterns of vector control coverage for malaria, including LLIN/ITN between 2003-2014
v) examine the association between LF prevalence and vector control coverage rates between 2003-2014
vi) map mosquito species distributions in relation to the LF sentinel sites and potential high-risk areas

3.4 Methods and materials

3.4.1 LF prevalence mapping from 2003 to 2011

The initial information on the geographical distribution of LF was based on two phases of mapping surveys conducted across Zambia by the Ministry of Health (MoH) Lymphatic Filariasis Control Programme (Phase 1: 2003–2005) and the Programme for Integrated Control of Neglected Tropical Diseases (Phase 2: 2009–2011). Details of the survey and locations are included in the annex.

3.4.1.1 **Phase I mapping surveys 2003-2005**

The first phase of the mapping surveys was conducted in 2003 and 2005 in 14 districts from the 9 provinces in Zambia 3 villages per district with 100 participants each were sampled making a total of 44 sites surveyed and a total of 4376 individuals tested. These surveys were conducted in accordance with the standard guideline from WHO (World Health Organization, 2000), which included adult individuals (>15 years of age) being tested for the presence of circulating filarial antigen (CFA; a marker of *W. bancrofti* adult worm infection) from finger-prick blood using the rapid immunochromatographic test card (ICT). Details of the survey

and locations are included in the supplementary file by Mwase et al (Mwase et al., 2014).

3.4.1.2 **Phase II mapping surveys 2009-2011**

As a National NTD Programme Manager I conducted the second phase of the LF cross sectional mapping surveys from 2009 to 2011 in the remaining 58 districts of the 9 provinces. Due to the high LF prevalence rates obtained in Kalabo district of Western Province in 2003, it was suggested that in addition to mapping all remaining districts Kalabo was included again in the second survey so as to validate the results of the earlier survey. The mapping survey was in line with the WHO operational guidelines on LF mapping to determine the disease prevalence and distribution (World Health Organization, 2000) for evidence-based interventions.

During the surveys in March 2009 each District Health Office identified three villages based on previous reports of LF or yearly positive malaria case reports received from all the facilities (Mwase et al., 2014). This was to use the malaria results as a proxy for a possible LF transmission since the two diseases share the same vector, mosquitoes. Each village had a 50km diameter area around. All the three villages were visited. The protocol was revised in June when only one village was sampled based on the new WHO guidelines. The next village was only considered if no individual tested positive for CFA in the first village.

All through the mapping surveys there was one survey team comprising of team leader, two laboratory technicians, two or three locally recruited nurses from the districts and a driver. The team upon arrival paid a courtesy call to the provincial and district health offices.

In 2009, mapping was conducted in March, June and December in 6 provinces:

- Luapula Province (Milenge, Kawambwa, Mwense, Nchelenge, Samfya, Mansa and Chiengi districts),
- Northern Province (Luwingu, Chilubi, Mpulungu, Isoka, Nakonde, Kasama, Mungwi, Kaputa, Mporokoso and Mpika districts),
- Central Province (Chibombo, Mkushi, Kapirimposhi and Kabwe districts),
- Lusaka Province (Lusaka and Chongwe districts), Western province (Mongu, Lukulu, Shangombo, Kalabo and Kaoma districts) and

- Northwestern Province (Mufumbwe, Mwinilunga, Kabompo, Solwezi, Chavuma and Kasempa districts).

In 2010 the surveys were conducted in January, July and August in the remaining three provinces and districts;

- Copperbelt Province (Lufwanyama, Luanshya, Masaiti, Kalulushi, Kitwe, Chingola, Mufulira, Ndola and Chililabombwe districts),
- Southern Province (Itezhi-tezhi, Gwembe, Monze, Kazungula, Namwala, Kalomo, Siavonga and Livingstone districts). Mazabuka was the only district mapped in 2011 (March).
- Eastern Provinces (Chipata, Mambwe, Petauke, Katete, Chadiza and Nyimba districts).

A total of 65 villages were identified. In each village 50-100 adults >15years were tested for CFA using ICT cards. If among the first 50 adults tested, more than 20% were positive, testing was stopped. Otherwise, testing continued until a total of 100 adults were examined. From each individual, 100 µl finger-prick blood was collected using a heparinized capillary tube. The blood was applied to the ICT test cards (Binax, Inc. USA). The results were read in the field 10 minutes after the cards were closed. Data on the number of persons examined, including the ID, sex, age and the results was collected in order to calculate the prevalence. The GPS readings were also collected at each village to measure the elevation of the area, the longitude and the latitude and the name of the location.

3.4.2 LF sentinel site survey from 2012 to 2014

In accordance with WHO guidelines on monitoring and evaluation to determine the progress of MDA implementation through the use of sentinel sites and spot check sites in each implementation unit (IU) (World Health Organization, 2013a), one sentinel site and one spot check sites by Implementation Unit (IU) was selected from the districts which will act as IU. Each selected IU had either a sentinel site or spot check site after a successful mapping and before MDAs baselines survey should be conducted. Therefore, prior to the administration of MDA for the elimination of LF, cross-sectional LF baseline sentinel site surveys were conducted in 2012 and 2014. Baseline surveys precede the MDA activities in order to have a base from which to

detect changes in LF prevalence over time and detect when mf is less than 1% (the critical threshold).

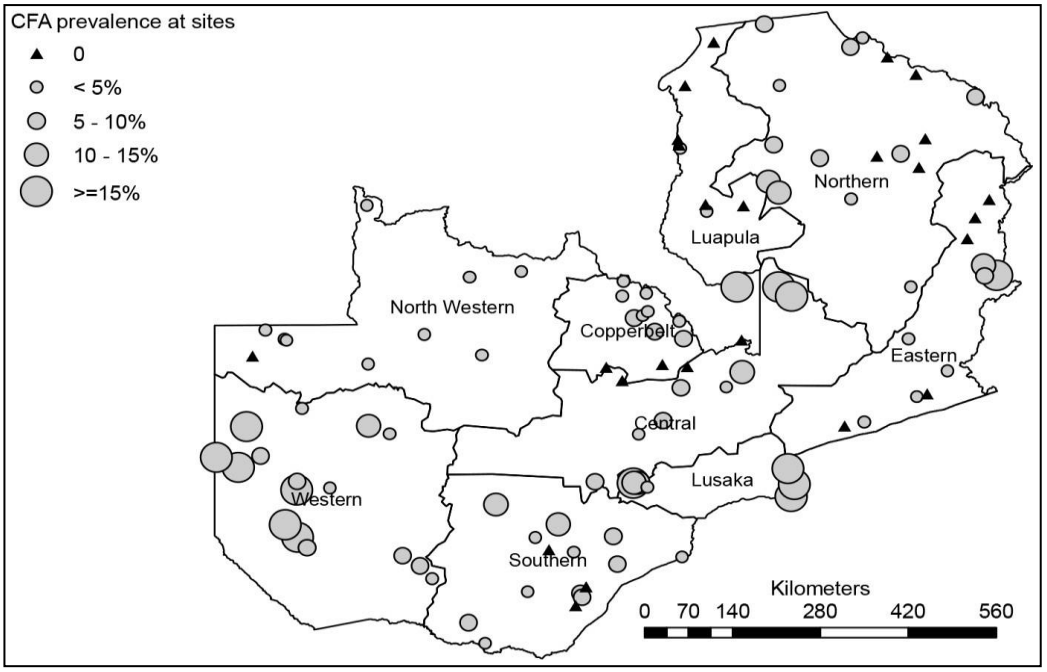


Figure 3-2 The map of Zambia showing survey sites and prevalence of CFA positive for LF

Results showing that LF is widely distributed in Zambia. Out of the 108 sites in 72 districts of the 9 provinces 78% of sites were positive for CFA (Mwase et al., 2014).

A total, of 40 sites from the original LF surveys site in Figure 3.2 were selected as sentinel sites based on the geographical distribution of the highest CFA prevalence rates as these would require a longer time to interrupt transmission. The first four sentinel site surveys were conducted in Western Province in October 2012 by 1 survey team, and a further 36 sentinel sites across the remaining provinces were surveyed from July to December 2014 by 4 survey teams. The teams comprised of a Team Leader, 2 laboratory technicians, field assistants from the selected IU and a driver. The teams upon arrival paid a courtesy call to the provincial and district health offices. The activity was part of standard routine monitoring and evaluation activities of the LF Programme to judge appropriate intervention scale. None of the sites selected had been previously used for M&E activities. In addition, these sites needed to have a stable population not affected by migration of at least 500 people.

During the surveys conducted in 2014,

- **Team** 1 visited Northern Province (Luwingu, Mpulungu and Mungwi districts), Muchinga province (Isoka, Mpika, Nakonde and Chinsali districts) and Luapula province (Milenge, Kawambwa, Nchelenge and Mwense districts).
- **Team** 2 visited Eastern province (Lundazi, Chipata, Mambwe and Nyimba districts) and Southern Province (Namwala, Itezhi-tezhi, Kazungula and Gwembe distrcits);
- **Team 3** visited Lusaka Province (Kafue, Luangwa and Chongwe)
- **Team 4** visited Copperbelt Province (Luanshya, Lufwanyama, Mufulira and Mpongwe) and Northwestern province (Kasempa, Mufumbwe, Chavuma and Solwezi districts)

Each site selected had at least a stable population of more than the required 500 people which enabled us to get samples from at least 200-300 randomly selected consenting individuals. During the survey individuals over the age of 5 years were recruited and tested for the presence of CFA using the ICT card. All individuals with positive ICT results were asked to return to the central location (mainly at the rural health centre), at night around 10 pm for a blood test in order to detect the presence of mf for *W. bancrofti* parasite, which is a marker of current infection, and which are only detectable in the peripheral blood at night (World Health Organization, 1997a). The counting chamber technique (CCT) and microscopy was used to detect mf on night blood slides (McMahon et al., 1979). Figure 3.3 shows positive results for both CFA and microfilaria. A standard specimen form was completed for each specimen taken with demographic data (ID, age, sex, village name) and history of LFtreatment.

A

B 

Figure 3-3 Positive CFA and microfilaria from the field study in Luangwa.

The pictures show in A. a positive CFA result with two red lines which appeared at 10 minutes. This was in a case from Luangwa district of Zambia in 2014. B is the positive microfilaria result from the same case. The mf was detected using the counting chamber technique during the study.

3.4.3 Changes in LF prevalence distribution between 2003-2014

To examine the association between LF prevalence and malaria vector control, this study compared the changes in LF prevalence between the prevalence mapping conducted between 2003-2010 and the baseline sentinel site mapping conducted prior to the MDA in 2012 and 2014, and the coverage rates of LLIN/ITNs and IRS coverage during the corresponding periods. Changes in prevalence between 2003 and 2014 were mapped using a combination of geographical information software including QGIS (www.) and ArcGIS (ESRI, Redlands, CA), The mean prevalence measures and confidence interval summarized at National and Provincial level to identify statistical differences in change in distributions over time. Data analyses

were conducted in Excel (Microsoft office 2016) or SPSS (IBM SPSS statistics 24 Data Editor).

3.4.4 Vector control distribution

3.4.4.1 Overview of vector control activities in Zambia

General information on malaria vector control was obtained from the Demographic Health Surveys for Zambia for 2007 and 2013, the malaria maps websites, general publications and global malaria reports. The national and provincial summaries on IVM coverage were obtained from the DHS datasets on distribution and utilization of insecticide-treated bed nets (ITNs) (https://www.dhsprogram.com/pubs/pdf/FR304/FR304.pdf), President's Malaria Initiative Reports (https://www.pmi.gov/where-we-work/zambia), WHO website (www.who.int/malaria/publications). This is of particular importance due to the same vector that transmits both malaria and lymphatic filariasis in this case the female anopheles mosquito. The information for each sentinel site was based on modelled Malaria Atlas Project data for ITNs from 2000 to 2015 used to examine thedistribution of ITNs http://www.map.ox.ac.uk/. In ARCGIS vector control data wereextracted and averaged within around a 50km radius/buffer of each sentinel site. In order to quantify the cumulative ITN coverage for each sentinel site, the annual meanpercentage was calculated for each site. Vector control in Zambia is mainly focused on ITN distribution targeted in rural areas and IRS, targeted in urban or peri-urban areas.

3.4.4.2 ITN coverage patterns 2003 to 2014 for each sentinel sites

To determine the extent of vector control in Zambia from 2003 to 2014, and the potential impact on LF prevalence rates, information on ITNs were obtained from modelled maps of coverage available from the Malaria Atlas Project (MAP) data (http://www.map.ox.ac.uk/). The MAP used spatial statistical methods to produce raster annual coverage maps for the entire African continent as shown in Figure 3.4. Information on ITN coverage rates across Zambia (Figure 3.5), and specifically for each of the sentinel sites in each year between 2003 and 2014, were extracted using the mapping software ArcGIS 10 and the zonal statistics tool (ESRI, Redlands, CA).

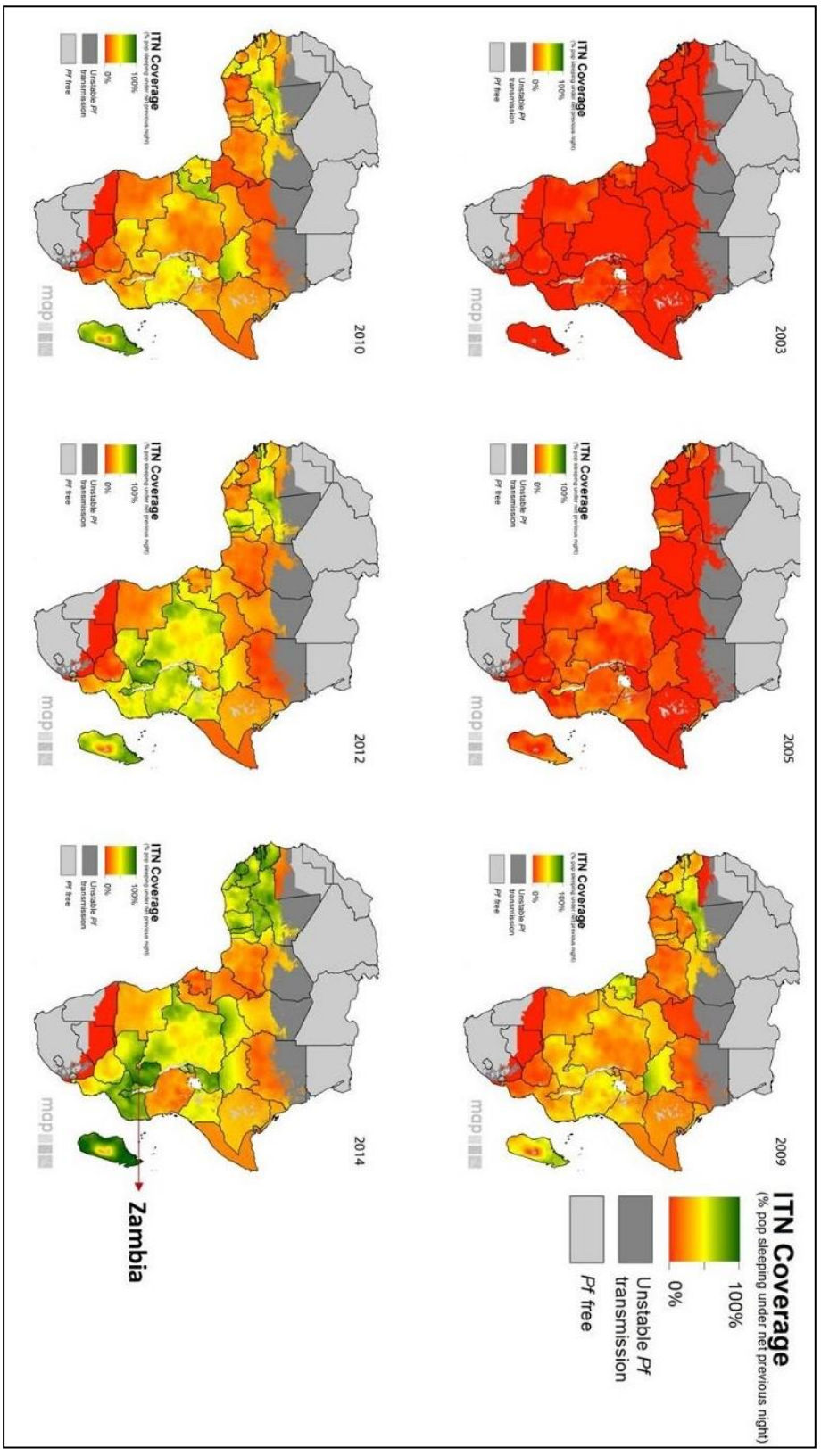


Figure 3-4 ITN Coverage across Sub-Sharan Africa between 2003-2014

The maps show the change in colour from red to green as the distribution of ITNs increase in Africa. The colour change is defined for Zambia (Pfeffer et al., 2018)

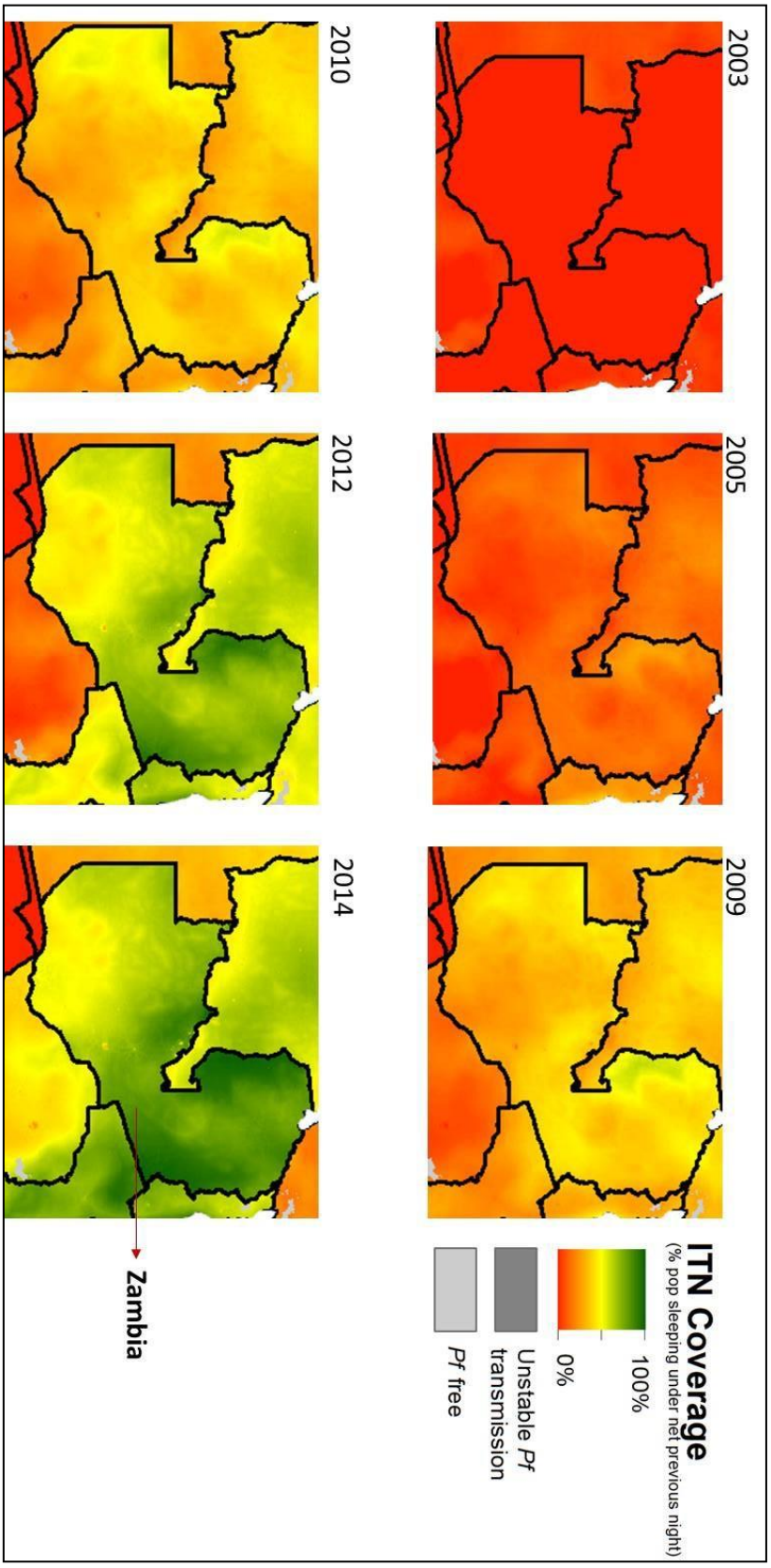


Figure 3-5 ITN Coverage across Zambia between 2003 and 2014

The Figure showing the map of Zambia change colour from red to green with the increase in INT distribution from 2003-2014 (Pfeffer et al., 2018)

Specifically, buffers, which are areas bounding region determined by a set of points at a specified maximum distance from all sentinel sites for proximity analysis were used with a uniform distance of a radius of 1 km, 5 km, 20 km and 50 km created around each sentinel site using the buffer tool in ArcMap. The average ITN coverage data within these radii for each year between 2003 and 2014 were extracted using the zonal statistics tool. For each LF prevalence measurement at a specific sentinel site in a particular year, the ITN coverage at each \sentinel site had similar radii (1km, 5km, 20 km and 50 km respectively) each of the same year of the LF prevalence measurement and was also extracted and tabulated for the four previous years. In addition, to develop models, elevation data was also considered and included, and taken from a publically available DEM (Hydrosheds) (http://www.hydrosheds.org/). Elevation data was extracted for each sentinel site sites from through the use of the Zonal Statistics tool in ArcMap (ESRI). Buffers of 50km radius were created and percentage ITN use for each year and each buffer were also extracted using the Zonal Statistics tool. These data points were used to create fields within the original SS dataset that represented the mean ITN percentage use in years relative to the year in which the prevalence was measured, e.g. 50kmBufferYear0 was the mean ITN percentage in the 50km buffer around the point in the year that the prevalence was taken. 50kmBufferYear4 was the mean ITN percentage in the 50km buffer around the point three years before the prevalence was taken.

3.4.5 Relationship between LF prevalence and ITN coverage

To better understand whether the observed reduction in prevalence over time was related to ITN coverage over the same period, first a Spearman's rank correlation two-tailed test was performed to measure the direction and association that exist between the LF prevalence and the ITN coverage values. Secondly, two statistical models were developed using LF prevalence and ITN coverage, and elevation data, using linear modelling (LM, function ‘lm’) within the R statistical environment (Crawley, 2012). Initially, a model (Model 1) that predicted the prevalence at each point in each year using only the ‘year’ and ‘elevation’ was created. The parsimony protocol outlined by Crawley as used to produce the Minimum Adequate Model (MAM), i.e. any non-significant values and interaction terms were removed sequentially from the highest order interactions downwards (Crawley, 2012)

At each step the significance of deleted items was assessed using analysis of variance using the Chi-squared statistic. As ITN coverage increased over time, it was important to ascertain whether the correlation between ITN use and a decline in LF prevalence could be ascribed only to this covariance. A second model (Model 2) was therefore created that incorporated ITN coverage data. The Chi-squared statistic was used to compare the two models in order to ascertain whether the addition of ITN coverage, added significantly to the model, and therefore whether ITN usage was a significant predictor of LF prevalence. Ho: Association of LogPrev ~ Year + Elevation = LogPrev ~ year4_5kmBednetX10 + Elevation

3.4.6 Distribution of mosquito species and insecticide resistance

3.4.6.1 Mosquito species

The information to determine mosquito species and their distribution at national, subnational, the LF sentinel sites and their resistance to insecticides was summarized from national malaria reports, President's Malaria Initiative Reports (https://www.pmi.gov/where-we-work/zambia), publications, IR Mapper, Malaria Atlas Project data and the WHO website (www.who.int/**malaria**/publications). From the available Africa wide maps, Zambia maps were used and imported onto QGIS/ArcGIS and from this information on mosquito species distribution and resistance was extracted.

3.4.6.2 Insecticide resistance in main *Anopheles* vectors

Information on insecticide resistance in Anopheles vectors was obtained form the various studies conducted in Zambia (Chanda et al., 2011) and other countries and published, the President's Malaria Initiative Reports and the WHO websites (http://apps.who.int/malaria/maps/threats/ or http://www.who.int/malaria/publications/vector-control/en/).

3.4.7 Ethical clearance

The field surveys were carried out as a part of the Zambian Ministry of Health (MoH) Lymphatic Filariasis Control Programme (2003–2005) and Programme for Integrated Control of Neglected Tropical Diseases (2009–2014), and followed protocols approved by the MoH for these programmes. Pre-survey meetings were conducted during which the selected communities and villages were given detailed

information about LF and the background, purpose and implications of the survey. Individuals volunteering to be examined provided oral informed consent under observation of both project staff and village authorities (parents/guardians consented on behalf of children below 15 years). Oral consent was the traditional way for making agreements in some of the survey areas, where written consent is unfamiliar and would cause suspicion and refusal to participate.

3.5 Results

LF prevalence surveys

Overall, there was a national decline in LF prevalence between 2003 and 2014 from 11.5% to 0.6% respectively as shown in Table 3.1 and Figure 3.6 which was also seen across the different provinces in the same Table and Figure 3.7

3.5.1 Results from mapping surveys conducted 2003 to 2011

The mapping sites and prevalence rates for surveys conducted from 2003 to 2011 are shown in Figure 3.8 A–B and graphs in Figure 3.9 A-B. For the years 2003 and 2005, a total of 4376 individuals from 42 sites across 14 districts in eight Provinces were examined during the first phase, of which 533 individuals were CFA positive with a 12.2% prevalence rates which was similar between males and females (males 199/1612=12.3%; females 334/2764=12.1%). Overall Western Province (27.4%) and Lusaka Province (25.6%) had the highest average rates (Table 3.1), with very high prevalence found at Nalibutu (54%), Lwandamo (53.3%) and Kaonga (50.6%) in Kalabo district, Western Province, and at Mphuka Kavalamanja (40.5%) Mphuka-Janeiro (33.3%) in Luangwa district, and Chanyanya (30%) in Kafue districts, Lusaka Province.

For the years 2009 and 2011, a further 5931 individuals from 66 sites across 58 districts in 9 Provinces were examined, of which 289 individuals were CFA positive with a 4.6% prevalence rate, showing a significant reduction in both males and females with a slightly higher rate in males (males 145/2123= 6.8%; females 144/3807=3.8%). Overall Northern Province (7.0%) and Southern Province (6.4%) had the highest average rates (Table 3-1), with very high prevalence found at Milenge East and Changwe Lungo (20.8%) in Milenge district, Luapula Province, at Mayukwayukwa (14.1%) in Kaoma district, Western Province and at Chitongo

(14.1%) in Namwala and Itezhitezhi (14.0%) in Itezhitezhi districts, Southern Province. During the two phases of the initial mapping survey, 14 districts from Northern (2), Copperbelt (1), Central (1), Eastern (2), Southern (2), Northwestern (1), Western (3) and Lusaka (2) were found to be non-endemic with LF prevalence rates <1%.

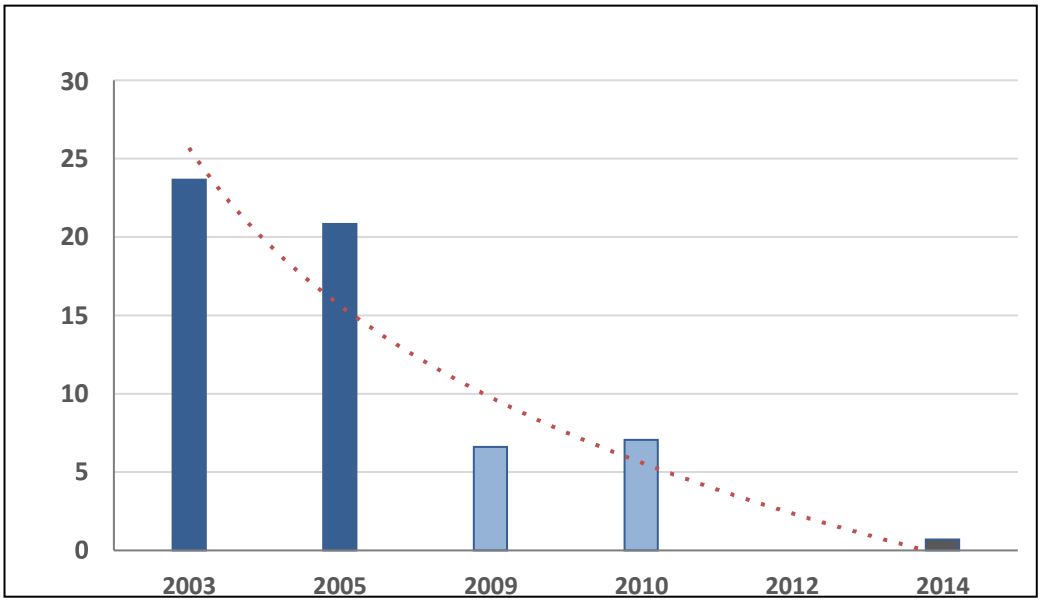


Figure 3-6 Graph showing the Average CFA prevalence for all 41 sites from 2003-2014

The Figure shows a significant downward trend in LF prevalence from 2003 to 2014 at the national level, From 24% to around 1%.

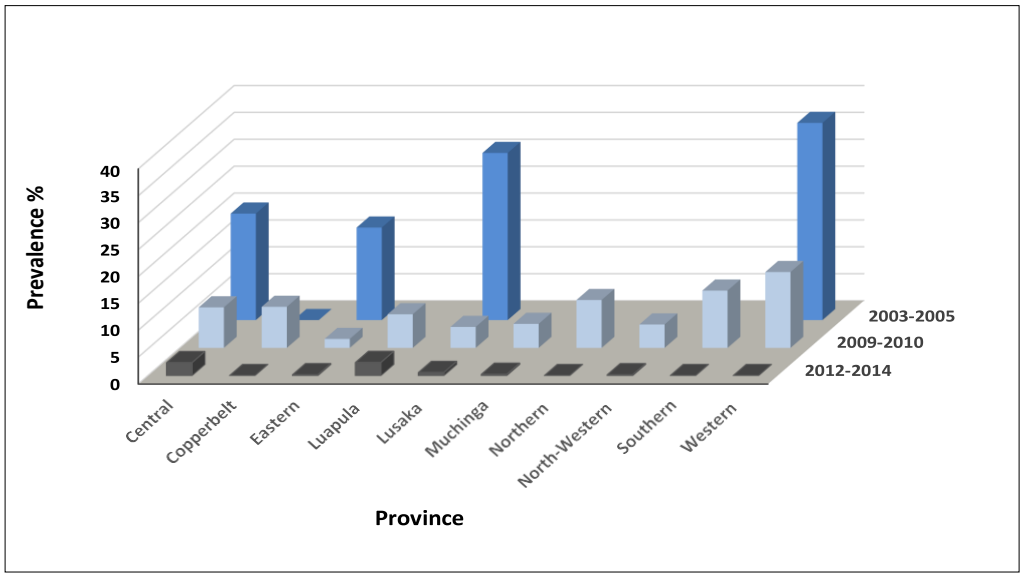


Figure 3-7 The average provincial LF prevalence from the mapping results and study site

The graph shows the provincial reduction in LF prevalence over the years. Provinces showed a complete reduction from 2003 to 2014. A more rapid decrease in Western and Lusaka Provinces and slow reduction in Luapula and Central Provinces. Mapping survey data was used to produce the graphs.

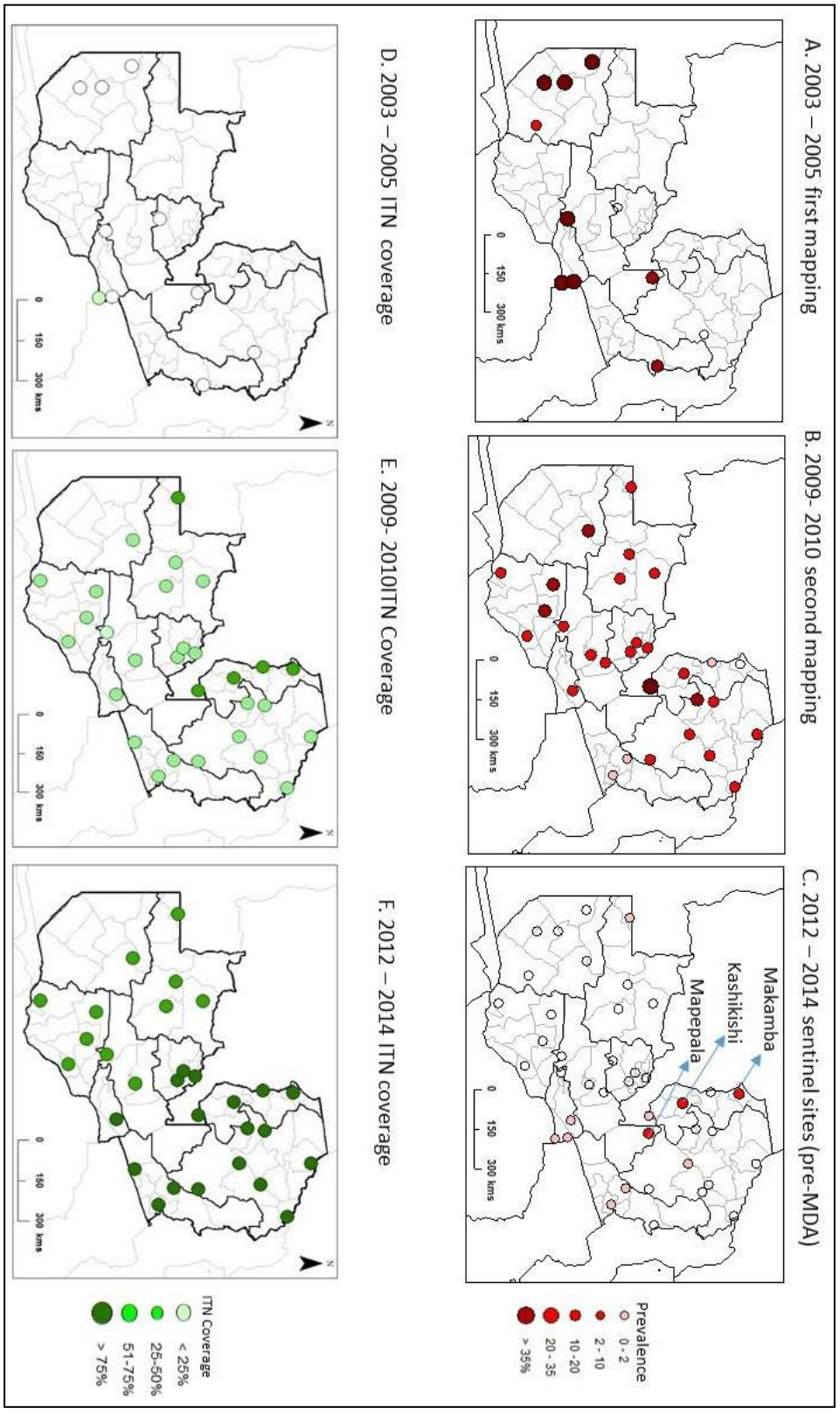


Figure 3-8 The maps of Zambia showing the LF prevalence and ITN coverage rates between 2003-2014

The maps I produced using the survey data shows LF point prevalence for 2003-2005 in A and 2009-2011 in B. C is showing the point prevalence of selected sites from A and B (sentinel sites). The same sites in A, B and C were selected for ITN coverage shown in D, E and F.

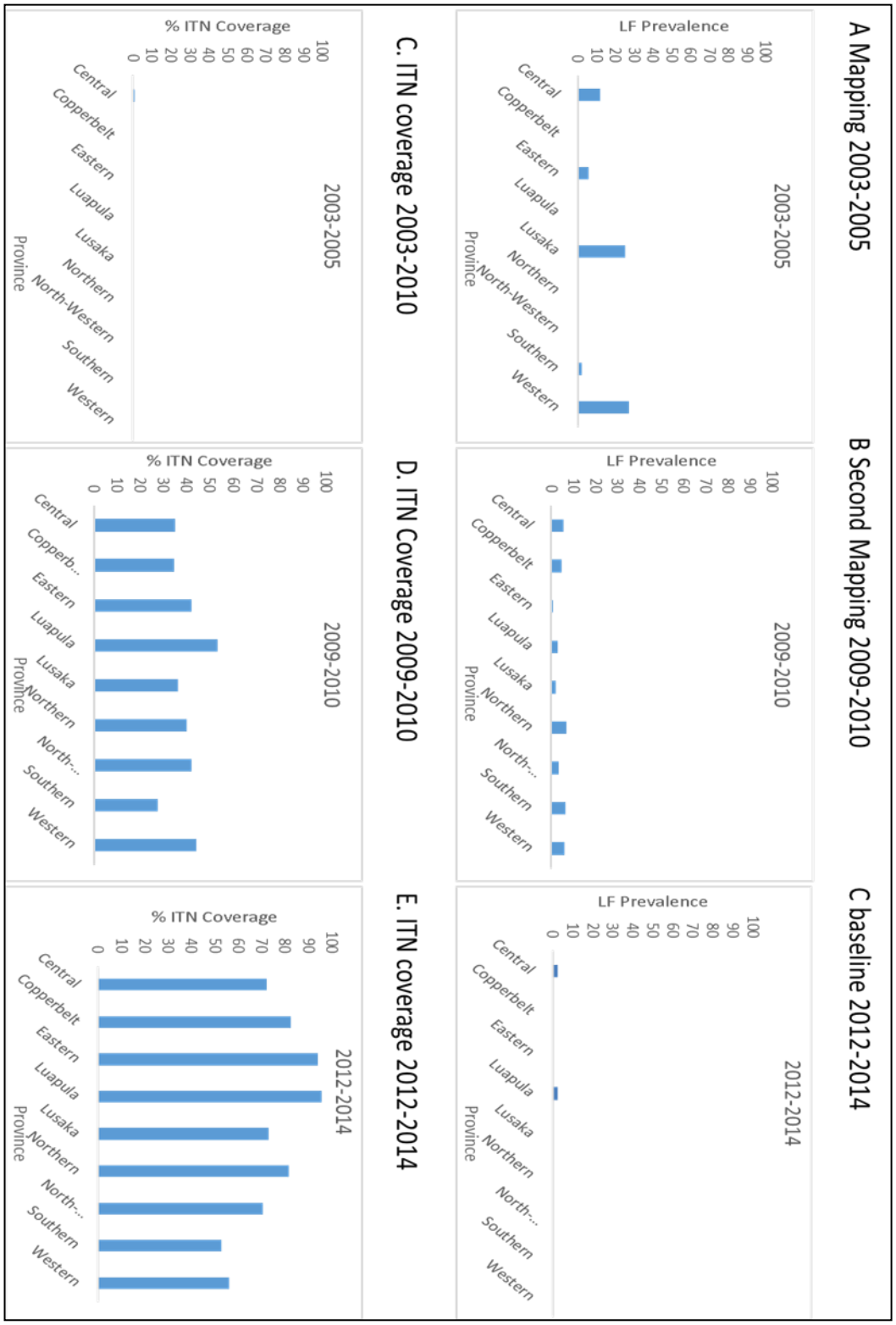


Figure 3-9 Graphs showing the prevalence rates over the years for LF and ITN coverage 2003-2014

The graphs show the mapping survey LF prevalence for 2003-2005 in A and 2009-2011 in B and baseline survey sites in C selected from A and B in 2012-2014. The maps in Figure 3.8 are reflected in Figure 3.9 in a graph form.

3.5.2 LF sentinel site survey 2012 – 2014

The prevalence rates from the sentinel site surveys conducted in 2012 and 2014 are shown in Figures 3.8 C and 3.9 C. A total of 10,995 individuals from the 40 sites across 37 districts in 9 provinces were examined, of which 72 individuals (0.6%) were CFA positive (0.9% of males; 0.5% of females). Overall, Luapula and Central Provinces had the highest prevalence rates at 2.5% each (Table 3-1). In Luapula Province, high prevalence was recorded at Makamba Rural Health Centre (5%) in Kawambwa District, and at Kashikishi RHC (4%) in Nchelenge District, while Central Province recorded the highest prevalence rates at Mapepala (9.7%) in Serenje District. The three sites were close to the border of Democratic Republic of Congo (DRC) (Figure 3.8 C). No individuals tested positive for CFA in Western, Southern and Copperbelt Provinces. Of the 72 CFA positive individuals, 25 (36%) were found to have mf (males 11/38 =28.9%, females 14/34=41.2%).

Overall, 80% (n=20) of the mf positive came from Luapula, 12% from Northern and 4% (1) each from Lusaka and Eastern Provinces. Notably, all the three CFA positive individuals in Mpika from Northern Province were found to have mf. When the overall prevalence at each sentinel site in 2003–2005 (11.5%) was compared to 2009–2010 (4.6%) and 2012–2014 (0.6%), a significant reduction (p value=0.000) was found. The decline was evident in all areas of the country (Table 3.1), and the differences are highlighted in Figure 3.8 panels A–C.

Table 3-1 Provincial LF prevalence and ITN coverage with confidence intervals

Province	LF prevalence (95% CI)			ITN coverage (95% CI)		
	2003–2005	**2009–2011**	**2012–2014**	**2003–2005**	**2009–2011**	**2012–2014**
Central	11.9 (0;38.0)	5.7 (2.3;9.1)	2.5 (0;10.1)	0.8 (0;4.3)	35.1 (28.2;42.0)	72.4 (53.2;91.8)
Copperbelt	0	4.5 (2.2;6.8)	0	0	34.5 (30.9;38.1)	82.4 (74.8;89.9)
Eastern	5.6 (0;12.7)	0.8 (0;1.6)	0.2 (0;0.5)	0	42.0 (40.2;43.7)	94.1 (88.9;99.2)
Luapula	–	2.8 (0;8.0)	2.5 (0;6.3)	–	53.4 (50.3;56.4)	95.6 (87.6;100)
Lusaka	25.1 (14.5;35.6)	2.0 (0;26.7)	0.6 (0;1.7)	0.2 (0;0.6)	36.1 (33;68.9)	73.2 (59.9;86.4)
Northern	0.2 (0;0.7)	6.9 (5.0;8.8)	0.1 (0;0.4)	0.5 (0.1;1.3)	39.8 (38.0;41.7)	81.6 (78.2;85.0)
North-Western	0.7 (0;2.6)	3.2 (1.7;4.7)	0.2 (0;0.7)	0	42.2 (34.4;49.9)	70.5 (63.9;77.1)
Southern	2.0 (0;4.9)	6.4 (3.1;9.7)	0	0	27.4 (25.9;28.8)	53.0 (48.3;57.7)
Western	27.5 (11.5;43.6)	6.2 (2.0;10.4)	0	0.06 (0;0.2)	44.0 (40.3;47.8)	56.3 (51.4;61.2)
Country	11.5 (6.6;16.4)	4.7 (3.6;5.7)	0.6 (0.03;1.1)	0.2 (0;0.3)	39.5 (37.4;41.6)	76.1 (71.4;80.7)

These rates are across three mapping time periods. At provincial level the LF prevalence declined with the increase in ITN coverage. note: 2009–2011 prevalence data include 65 sites from 2009 to 2010, and one site from early 2011. The maps in Figure 3.8 and the graphs in Figure 3.9 are a reflection of the data in this table.

3.5.3 Change in vector control distribution coverage rate 2003-2014

Three main climatic factors that affect malaria transmission are *temperature, rainfall* and *relative humidity.* The functional relationship between the most important continuous environmental predictor variables and the predicted Odds ratio of presence of either ≥ 5% or ≥ 15% CFA was explained by an illustration with the distance to nearest surface water bodies scoring the highest Odds ratio of occurrence of LF (Mwase et al., 2014).

Zambia has a long history in vector control with different interventions being implemented over the years. Towards the end of the 20th century the main focus was on treatment of malaria cases with very little preventive measures. After 2000, vector control interventions were introduced by the Ministry with support from PMI (President's Malaria Initiative and United States Agency for International Development, 2007, President's Malaria Initiative and United States Agency for International Development, 2009), however, implementation was not systematic as it was dependent on the availability of resources. Two main vector control strategies have been scaled-up in Zambia including ITN distribution and IRS by the Zambia National Malaria Control Program with the aim to achieve 100% vector control in all at risk areas by the end of 2017 (President's Malaria Initiative and United States Agency for International Development, 2009). This recent initiative started in 2003 and aims to achieve and sustain a universal ITN coverage and a focused IRS programme in urban and peri-urban areas supported by PMI (President's Malaria Initiative and United States Agency for International Development, 2010, President's Malaria Initiative and United States Agency for International Development, 2015). However, IRS has been erratic over the years ranging from 2% to 55% peaking from 2008-2011. During my study only ITNs data was used as it was consistent in terms of being scaled up.

In 2005, following the launch of malaria control scale-up, Zambia conducted a nationwide ITN distribution. The distribution of ITNs is an ongoing activity and the last mass campaign was in 2013/2014 covering all the provinces and 77% household owned at least 1 ITN. At provincial level, the highest was Eastern Province at 94% coverage and the lowest in Lusaka at 52%. The next mass campaign is planned for in 2017 in order to attain universal coverage.

IRS was introduced in 2000 but at a very small scale on the Copperbelt. In 2003/2004 the government restarted the programme in 5 districts and scaled up to 8 in 2004/2005. IRS has also been scaled up over the years in targeted districts. The last campaign in 2013/2014 covered 28.9% households protecting just over 2 million people. In the same year 80.6% of households reported availability of at least one form of vector control method (IRS or ITN) with 25.3% having received both. The two maps shown in Figure 3.4 and 3.5 show an upward trend in the coverage of ITN distribution and IRS.

ITN coverage rates at sentinel sites

The ITN coverage rates for the sites in the two mapping surveys conducted from 2003 to 2011 and the sentinel sites in 2012–2014 are shown in Figures 3.7 D–F. The overall coverage across all the sites was 0.1% in (2005), 26.0% (2006), 37.0% (2007), 37.0% (2008), 39.5% (2009), 39.7% (2010), 51% (2011), 66% (2012), 70.7% (2013), 76.0% (2014) and 76.0% (2015) clearly indicating a staged increase in coverage.

For the sites surveyed for LF in the years 2003–2005, the average ITN coverage in the same year was 0.2% (Table3.1). The majority of sites had no ITN coverage above 1% except for Luangwa district, Lusaka Province which had 1.6% coverageas indicated in Figure 3.9 D. For the sites surveyed in the years 2009–2011, the average ITN coverage was 39.5% with the highest coverage was in Luapula Province (53.4%) and Western Province (44.0%) and the lowest reported in Southern Province (27.4%) (Table 3.1) and Figure 3.9 E. The highest ITN coverage was found at Makamba (61.0%) in Kawambwa district and at Lubunda chiefdom (56.0%) in Mwense district in Luapaula Province and Shangombo-Kanja Nangweshi (49.5%) and Itufa-Litambya in Senanga (49.0%) in Western Province, whilst the lowest was at Chitongo RHC (25.0%) in Namwala district and at Munyumbwe–26.0%) in Gwembe district of Southern Province.

For the sentinel sites conducted in the years 2012–2014, overall the ITN coverage was 71.0% with the highest coverage reported in Luapula Province (95.9%) and Eastern province (94.1%) and the lowest reported in Southern (53.0%) (Tables 3.1) and Figure 3.7 F and 3.9 F. The highest ITN coverage was found at Makamaba (96%) and Lubunda Chiefdom (96.2%) Mwense district in Luapula Province and at Madzimoyo HC (92%) in Chipata district and at Mwase-Lunda (90.9%) in Lundazi

district of Eastern Province whilst the lowest was reported at Itezhi-tezhi Urban Health Centre (47.8%) in Itezhi-tezhi and at Makunka RHC and Chitongo RHC both at 48% of Kazungula and Namwala districts respectively in Southern Province. Figure 3.6 shows how over the years from 2003 to 2014 the trend line LF prevalence is decreasing and in Figure 3.7 how these compare over the years. On the other hand, Figure 3.10 is showing the increase in ITN and IRS have been increased over the same years in the sentinel sites with an upward trend.

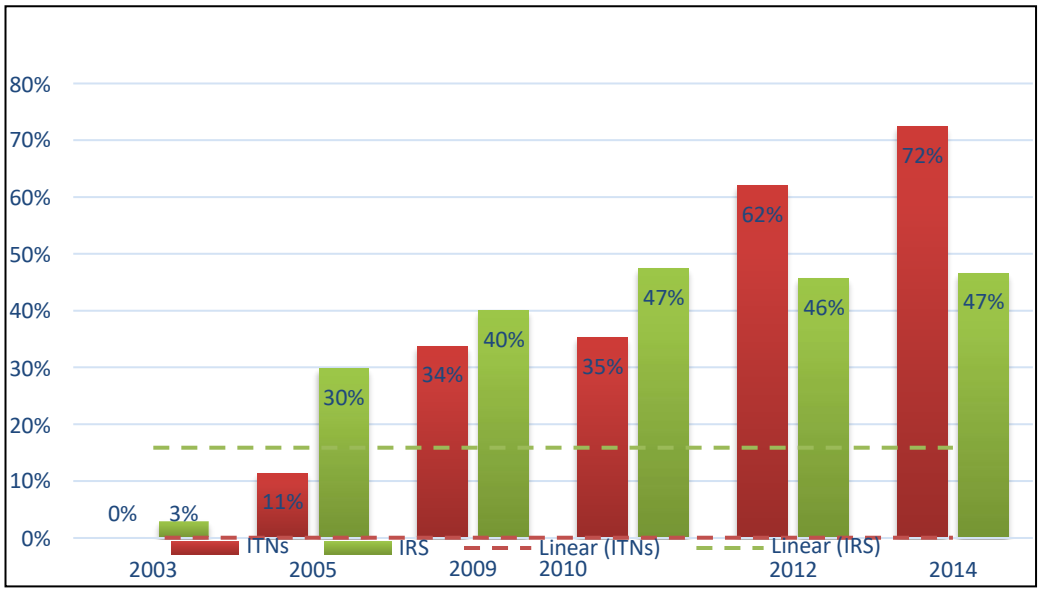


Figure 3-10 Overall national average coverage rates of ITNs and IRS at each study site from 2003-2014

The Figure shows two graphs representing the same data in a linear and bar chat representation. Both charts show an upward trend of ITN and IRS coverage from 2003 – 2014.

3.5.4 Relationship between LF prevalence and ITN

The relationship between LF prevalence and ITN coverage was performed using Spearman's correlation and the Linear modelling in R. There was a negative association between LF prevalence and ITN coverage at the 5 km radius and at 4 years prior to the LF prevalence value being measured with the Spearman's Correlation, with a significant Spearman's rho correlation of -0.462 at 0.01 level (2-tailed). Similar but less significant correlations were found at other radii and for other years. A scatter chart of the data suggested a non-linear relationship; prevalencewas transformed using log10(n+1) to allow for a linear modelling approach.

Further, using linear modelling in R, a model predicting prevalence from elevation and year was created, which resulted in an R2 value of 0.1878; Year being

the most significant factor. The addition of average ITN coverage (specifically in a 5 km buffer, four years before the prevalence was measured - chosen due to it being the most significant relationship found in the Spearman correlation) to the model increased the R2 value to 0.2837 with ITN coverage being the most significant factor. The minimum age model (MAM) when including ITN coverage did not also include year, as this variable did not add significantly to the model. The R-squared test confirms that this is a significant difference from Model 1, therefore confirming that ITN coverage combined with elevation was found to be a better predictor of LF prevalence than year combined with elevation. A summary of the two models are presented in Table 3-2 below.

Table 3-2 Showing comparison between Model 1 without and Model 2 with bednet coverage

Multiple R^2 > in model 2 there better explains variation when bednet coverage is assessed. The p-value is more statistically significant in model 2 than 1 and therefore rejects the Ho.

Model 1: LogPrev ~ Year + Elevation				
Multiple R-squared		0.1878		
Adjusted R squared		0.1772		
F-statistic		17.69 on 2 and 153 Df		
p-value		1.228e-07		
	Coefficients	Standard Error	t-score	p>|t|
Intercept	1.040e+02	1.910e+01	5.444	2.03e-07***
Year _Prev	-5.140e-02	9.509e-03	-5405	2.43e-07***
Elevation	-2.185e-04	1.077e-04	-2.029	0.0442*
Model 2: LogPrev ~ year4_5kmBednetX10 + Elevation				
Multiple R squared		0.2837		
Adjusted R squared		0.2744		
F-statistic		30.3 on 2 and 153df		
p-value		8.201e-12		
	Coefficients	Standard error	t-score	P>|t|
Intercept	0.9343864	0.1085368	8.609	8.37e-15***

Year4_5kmBednetX10	-1.3874188	0.1894731	-7.323	1.30e-11***
Elevation	-0.0002639	0.0001008	-2.618	0.00972**

3.5.5 Mosquitoes species distributions in relation to the sentinel sites and potential hotspots of LF transmission

The major mosquito species in Zambia are *An. arabiensis*, *An. funestus* and *An. gambiae.* These are distributed in varying levels across the country as shown by the modelled Odds ratio distributions for each district in Figure 3.11 A-F.

3.5.5.1 Mosquito species distributions

An. gambiae was found to be highest in Luapula Province with a provincial mean presence Odds Ratio of 59% followed by Copperbelt at 45% and Northern Province at 39%. The lowest was in Western province at 0.08 and Southern 0.12. At the district, high levels of occurrence were in Chiengi, Kawambwa, Mwense, Nchelenge and Mansa, all from northern part of the country.

An. funetsus forms the largest population of the anopheles mosquito species. Its occurrence is nationwide in high densities. *An. funestus* is highest in Lusaka Province with a mean of 0.85, followed by Central Province at 0.78 and Southern Province at 0.73. The lowest occurrence is Luapula Province at 0.45 and Northern Province 0.51. At the district, high levels of occurrence are in Kabwe, Chibombo, Kaoma, Kafue and Lusaka from the central part of the country.

An. arabiensis is found in slightly higher levels than *An. gambiae* in varying levels across the country. An. Arabiensis is highest in Western province with a mean of 0.68, followed by Southern Province at 0.63 and Luapula and Central provinces both at 0.47. The lowest occurrence is in Northwestern at 0.28, Copperbelt 0.34 and Lusaka at 0.36. See Figure 3.9. At district level, high levels of occurrence are in Kalomo, Kalabo, Samfya, Mongu and Monze mainly in the southern part of the country.

3.5.6 Evidence of insecticide resistance

Because of the massive vector control interventions involving ITN and IRS, resistance to the chemicals such as DDT and pyrethroids that have been used over

the past 10 years has been reported across the country as shown in Figure 3-11. From 2010 to 2015 *An. funestus* was reported to be resistant to carbamates (35%), organochlorides (35%), organophosphates (0.2%) and pyrethroids (67%). During the same period *An. gambiae* was reported to be resistant to carbamates (17%), organochlorides (27%), organophosphates (9%) and pyrethroids (21%). The widespread resistance to pyrethroids and carbamates especially in Luapula, Northern and Eastern parts of the country has seen resurgence in malaria cases (Thomsen et al., 2014).

3.5.7 Relationship between mosquito species potential hotspots of transmission

The occurrence of the mosquito species at the LF sentinel site "hotspots" with ongoing transmission is at varying levels. From the baseline surveys, the highest mf was in Kawambwa and Nchelenge in Luapula Province (see Figure 3.8 C). These two districts have high levels of *An. gambiae* which is 0.71 and 0.67, *An. fenustus* at 0.29 and 0.43 and *An. arabiensis* at 0.36 and 0.35 respectively as shown in Figure 3.11. The districts also have high level of insecticide resistance as seen in Figure 3.12

The other districts with positive mf are Mpika in Northern Province, Luangwa in Lusaka Province at the border with Eastern Province and Chipata in Eastern. They have a high occurrence of *An. fenustus* at 0.63, 0.82 and 0.85 respectively. *An. gambiae* is at 0.23, 0.21 and 0.31 while *An. arabiensis* is at 0.36, 0.23 and 0.54 in the three districts, respectively. The mosquitoes in these districts have also shown high resistance to pyrethroids and carbamates (Thomsen et al., 2014). In Kawambwa the *An. funestus* mortality rate to pyrethroid and carbamate was 46% and 14% respectively (Thomsen et al., 2014).

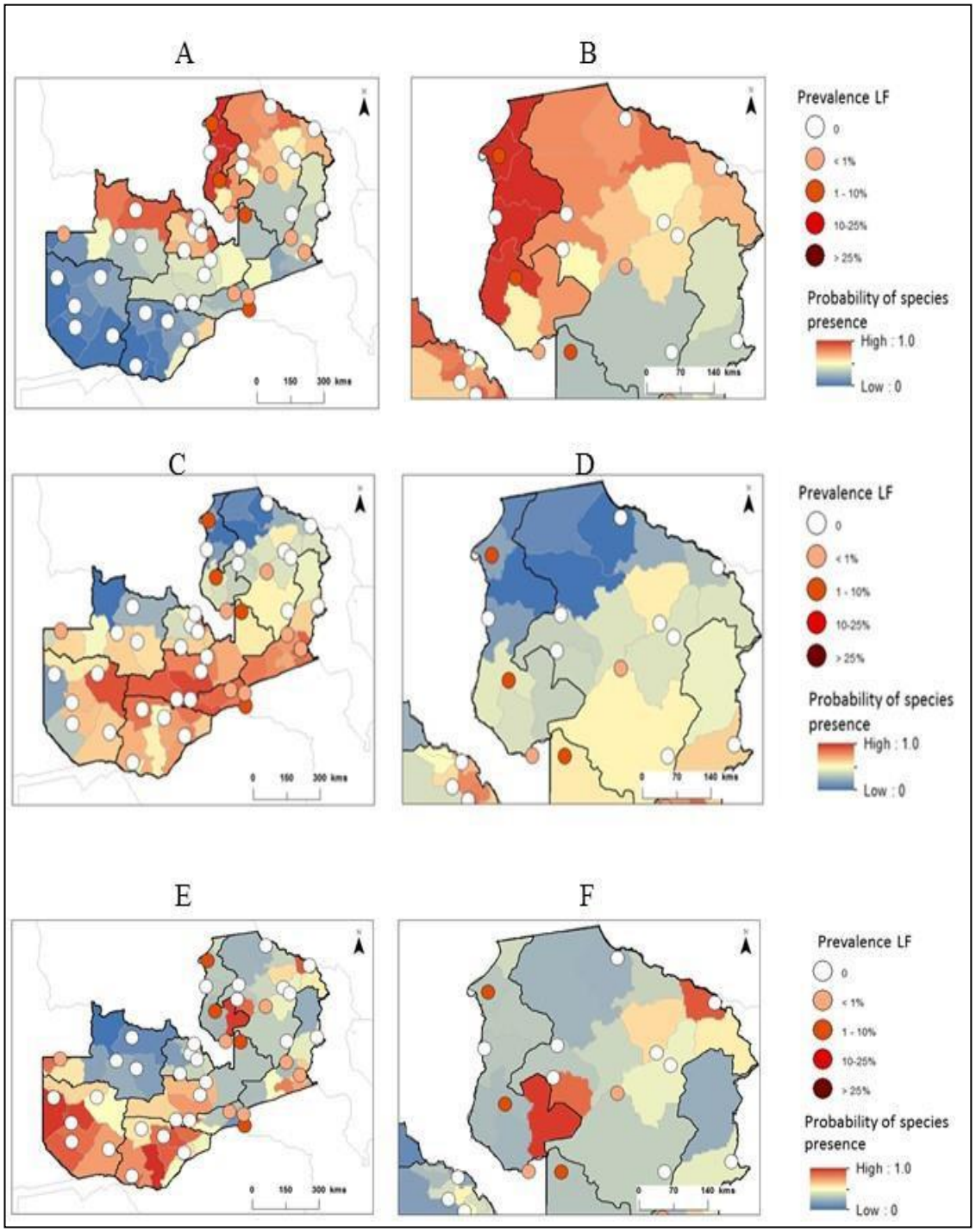


Figure 3-11 The maps showing the distribution of anopheles mosquitoes in the LF study sites

The map in A and B shows the *An gambiae* in relation to the sentinel sites and the potential hot spots. C and D Show *An. funestus* in relation to sentinel sites and the potential hotspots while E and F show *An. arabiensis* in relation to sentinel sites and the potential hotspots. There is a focus on Luapula or the northern part of the country because of the high *An gambiae*, high LF prevalence and as will be seen in figure 3.12 where there is a high resistance to insecticide. (Wiebe et al., 2017)

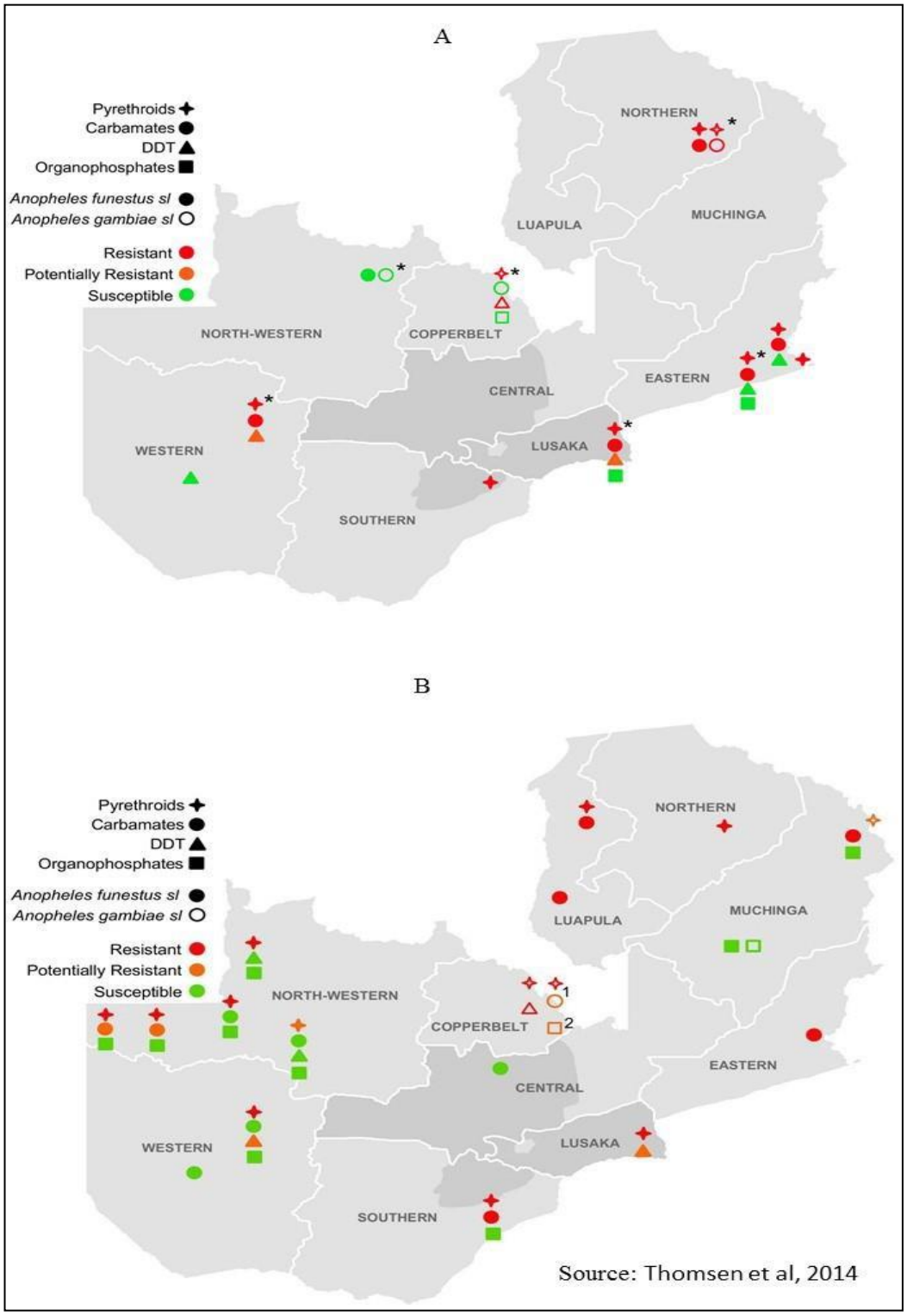


Figure 3-12 Maps showing insecticide resistance to different species and to different insecticide classes

Map A shows Insecticide resistance in collections from March 2011–April 2012. Darker grey shading indicates areas surveyed in locations with microarray data. Map B shows Insecticide resistance in collections from May 2012–April 2013. Darker grey shading indicates areas surveyed Potentially resistant to bendiocarb but susceptible to propoxur. 2Potentially resistant to pirimiphos-methyl but susceptible to malathion (Thomsen et al., 2014)

3.6 Discussion

This chapter highlights the significant decline of LF prevalence across the country between 2003 and 2014. This is of particular importance for the National LF Programme as the very low levels of infection found before the start of mass distribution of albendazole and DEC suggests that other factors contributed to this widespread reduction in prevalence. Evidence elsewhere suggests that the long-running MDA programmes for onchocerciasis using ivermectin may have impacted on LF transmission (Ramaiah and Ottesen, 2014, Koroma et al., 2013). Therefore, an understanding of the extent of all overlapping interventions is important (Kelly-Hope et al., 2011). However, as Zambia is not endemic for onchocerciasis and has never benefitted from an ivermectin MDA programme, it is likely that the significant geographical scale up of ITN coverage for malaria is one factor that has impacted on LF transmission (Kelly-Hope et al., 2013), as evidenced in other LF endemic countries where *Anopheles* are the main vectors (van den Berg et al., 2013).

The observed contrasting LF prevalence and ITN coverage rates suggest that synergies between the LF and malaria control programmes should be further strengthened in Zambia given the potential benefits. The first model showed a decline in prevalence. However, the second model including ITN coverage in a 5 km buffer around each site and consisting of two elements (variation in ITN coverage over time and variation in ITN coverage geographically), showed a higher R2 value. This suggests that geographical variations in ITN coverage may have influenced the prevalence of LF, as well as the temporal variation that was previously explained using the year variable. Whilst this does suggest a role of ITNs in the control of LF, there may be other confounding factors such as environmental changes, human development and/or indoor residual spraying (IRS) (Kamuliwo et al., 2013) occurring over the same period in a similar geographical pattern that cannot be discounted.

An issue that is not clear from the data or the results is whether there is a causal relationship between ITN coverage and LF prevalence, and in which direction this relationship might be. If the roll-out of ITNs was faster in areas with a higher initial prevalence of LF, the reduction in the prevalence of LF would have been seen much earlier due to the strong correlation between ITN coverage and LF prevalence. However, the limitation to the study is that there is no evidence on the utilisation of

the ITNs but just the increase in coverage. It is therefore an assumption that with the increase in the distribution of ITNs, there is a relative increase in the utilisation hence the protection from mosquito bites and further transmission of the microfilaria. All that can be said is that the ITN coverage is more closely associated with LF prevalence than year alone. Interestingly the best predictor is not the ITN coverage in the year that prevalence was measured, but rather ITN coverage four years previously. Similarly, the radius around the sentinel sites provided the most significant relationship was 5 km and may reflect the distance within which people live.

Furthermore, a recent study has denounced the causal relation between vector control using IRS and ITN because mosquitoes are resistant to more than 80% of the insecticide used to treat the nets and spray houses. High levels of insecticide resistance were observed for five out of six insecticides tested, with the lowest mortality (0.97%) reported to permethrin, while for DDT, lambdacyhalothrin, bendiocarb and deltamethrin the mortality rate ranged from 1.63–3.29%. However, synergist assays using the P450 inhibitor PBO, or the esterase inhibitor TPP resulted in markedly increased mortality (to ≈80%), suggesting a role of metabolic resistance in the resistance phenotype (Silva Martins et al., 2019). More new novel techniques should be explored further to resolve the long-lasting problem of insecticide resistance. The long use of insecticides for vector control has successfully reduced the burden of vector-borne diseases worldwide, but it has also had negative impacts that the recurrent and extensive application of insecticides in endemic regions has also triggered an increase in the level of insensitivity to the recommended insecticides (Rivero et al., 2010) which is retrogressive to the public health. The mosquito resistance to a number of insecticides is well documented and that is why programmes, research scientists should shift their focus on producing newer effective insecticide that will kill mosquitoes.

Due to the small number of data points available, especially for later years and the universal dramatic drop in LF prevalence, a spatial model was not attempted for this analysis. However, consideration of spatial factors would be valuable if more data were available and may be a consideration for the future surveillance strategies, which could also be integrated with malaria activities. With sound policies attracting partners, and funding for malaria control high, there is mounting evidence of the

positive health impacts from malaria control in the country. For example, malaria parasite prevalence in the under-five year old reduced by 50% over a two-year period (21.8% in 2006 to 10.4% in 2008). A further 67% reduction in parasitic prevalence in infants was noted (Chizema-Kawesha et al., 2010) with an incremental overall reduction in infection transmission in those who use a combination of ITNs and IRS (Chanda et al., 2013). This is also reflected in the World Malaria Report of 2013 where malaria hospital admission and death have dramatically fallen between 2001 and 2012.

Given that LF and malaria are transmitted by the same *Anopheles* species, it is likely that the malaria interventions reducing malaria prevalence over the past decade, have simultaneously impacted on LF transmission, thus reducing the prevalence significantly before the scale up on MDA in 2015 (Kelly-Hope et al., 2013). It is also important to note that Zambia was one of the few countries in sub-Saharan Africa to achieve high coverage of untreated or hand-treated bed nets in the early 2000s, suggesting that the actual net coverage and associated impact could have been higher. Further, one of the main objectives of the National Malaria Control Action Plan in 2010 was to ensure universal coverage of long-lasting insecticidal nets (LLINs) through appropriate channels by December to 2011 and maintained through to 2015. As part of the GPELF strategy, the WHO highlights the importance of vector control to enhance the elimination of LF and emphasises the need for long term relationship between the two programmes (World Health Organization, 2015). Bockarie also highlighted the potential benefits and the role of vector control in LF programmes, especially where *W. bancrofti* was the main parasite and indicated that the combination of MDA and ITNs reduced transmission by 90% (Bockarie et al., 2009a).

The potential interruption of LF transmission in most regions of Zambia is a positive outcome for the LF programme, despite the slow start of MDA intervention and being behind targets at the GPELF halfway mark in 2010 (Harrington et al., 2013). This observation suggests that the WHO recommended 5-6 rounds of MDA required to interrupt transmission, may potentially be reduced to fewer rounds of MDA with the consultation and agreement of the AFRO Regional Programme Review Group (RPRG). This will enable the LF programme to potentially finish MDA in 2018, start surveillance activities and focus on any persistent areas with

targeted interventions. This will help the programme to meet the GPELF elimination goals by decreasing the population at risk and requiring preventive chemotherapy by 11 million people (Zambian population living in endemic districts). Specific follow-up assessments will need to be prioritised to areas still showing evidence of ongoing transmission, especially those bordering the DRC, which may be attributed to cross-border migration. However, a similar situation in this area is evident with malaria transmission that is persisting despite the extensive distribution of ITN interventions, which suggest that the problem could also be related to other factors such as mosquitoes being resistant to the insecticides used for ITNs (Chanda et al., 2011, Wiebe et al., 2017).

In addition, due to Zambia's nature of being a landlocked country with porous borders her plan to eliminate malaria and subsequently LF may take longer than anticipated. Enhancing cross-border collaboration by carrying out joint planning and implementation of joint interventions for effective control of malaria across borders. This should be encouraged as the countries fight a common problem. This will then push the county to elimination. Donors who at times are biased in the allocation of funds should support cross-border collaboration to eliminate malaria (World Health Organization, 2018b). However, the dependency on donors to prevent and control diseases should not be encouraged, and countries should move to domestic funding. Zambia is one country that is pushing for health insurance, sin taxes and partnerships to improve the quality of the health service delivery (Government of the Republic of Zambia, 2017b) and malaria will benefit from these innovations under health care financing.

Moving forward, the LF programmes will need to concentrate on the "endgame surveillance" strategies that will be most effective. The LF programme should aim to integrate key monitoring activities with the malaria control programme to optimise human, technical and financial resources in the long-term, this may include xeno-monitoring of infection in the mosquitoes by both parasites, and will be very important even when mf infection declines in humans, to confirm similar decline of mf infection in the mosquitoes and monitor any possibility of recrudescence (Bockarie et al., 2009a). Identification of areas with persistent LF or where mosquitoes are resistant to the insecticides used with ITNs and IRS, will help to focus interventions (Coleman et al., 2017). The districts bordering DRC where there was

evidence of ongoing transmission should be investigated further and surveillance strengthened. It may be that the triple drug treatment using DEC, albendazole and ivermectin (Irvine et al., 2017, Thomsen et al., 2016) could be used in any remaining hotspots to accelerate progress to meet the national and global targets of LF elimination by 2020. Such multipronged approaches will maximise the use of interventions and resources, and build synergies between the programmes, which will help to strengthen health systems at all levels.

3.7 Conclusion

The study has provided additional evidence on the correlation between vector control and LF prevalence. The putative synergy of LF prevalence with vector control has helped to put Zambia on track to meet national and global goals of LF elimination by 2020, despite the late commencement of intervention. This has accepted the research hypothesis: Increase in ITN coverage reduces the LF prevalence rates due to the statistically significant correlation of LF prevalence and ITN coverage.

Although the study has generated evidence for the national LF elimination programme, useful information to further improve the programme implementation is required. There is a need to further assess the persistent high prevalence in the border areas with Democratic Republic of Congo. The country also needs to collect data on the prevalence of filarial morbidity and learn lessons from a review of the available literature on its entire management within the region and globally. Another big question is why we need to continue with 5 or more rounds of MDA, which is quite expensive when the affected population can be treated once. Additional research to develop medicines that can kill the adult parasite should be conducted.

3.8 Author contributions

Mutale Nsakashalo-Senkwe: field work, data collation, preliminary analysis, first draft of paper.

Enala Mwase, Elizabeth Chizema, Victor Mukonka, Peter Songolo, Freddie Masaninga: in-country field and data support.

Brent Thomas: field work, data collection and collation.

Maria Rebollo, Moses Bockarie: fieldwork work in Western Province.

Russ Stothard: data analysis and draft of paper.

Hannah Betts: statistics and model development.

Louise Kelly-Hope: field work, concept of paper, analysis, maps, first draft of paper. All authors contributed to the published manuscript.

Chapter 4 Mapping the distribution of schistosomiasis and soil transmitted helminthiasis in Zambia

4.1 Abstract

Background: Schistosomiasis (SCH) and soil transmitted helminthiasis (STH) are widely spread in Zambia at varying prevalence rates from low to high. SCH is caused by *Schistosoma haeamatobium* and *Schitosoma mansoni*, and STH by hookworm, *Ascaris lumbricoides* and *Trichuria trichuris* for STH.

Methodology: National cross-sectional descriptive school-based study in 72 districts of Zambia. 20 schools were randomly selected per district in all the quadrants of the district. Stool and urine samples were collected from 30 children per school aged 10-14 years. Urine was examined using urine filtration and dipstick, while stool was examined using the Kato Katz technique. Descriptive analysis using IBM Statistical Package for Social Science Version 26 (IBM SPSS 26) on the study data to estimate the prevalence rates and endemicity of SCH and STH. Map were produced using the QGIS and spatial clustering using ArcGIS.

Principal findings: 39,904 children tested for SCH and STH in 1349 schools. The overall prevalence for schistosomiasis is 16.6 % while STH was 22.0 %. The highest prevalence reported in Lusaka (65.3 %) and Northwestern (41.9 %) for SCH and STH respectively. Most participants were aged 10-12 years and also had the highest prevalence of *S. haematobium* followed by 13-15 years who had the highest prevalence of hookworm. Pearson Chi-Square test on age group indicated statistically significant difference at 4 degrees of freedom X^2=372.766 (*S. mansoni*), X^2=353.108, (hookworm) and X^2=94.965 *(A. lumbricoides)* at $p<0.0005$. Univariate and multivariate analysis revealed correlation on the independent environmental and climatic predictors with SCH and STH prevalence.

Conclusion: The distribution of SCH and STH is widespread with varying risks of transmission. The maps produced will provide the evidence on the areas targeted for interventions in Zambia.

4.2 Introduction

Recently, there has been advocacy to integrate the control and management of neglected tropical diseases. The Global Network for Neglected Tropical Diseases (GNNTD) has been instrumental in raising awareness and promoting advocacy relating to the NTDs (Toledo et al., 2016). The initiative has provided funding to national health programmes, through partner collaborations, and other key stakeholders in order to examine existing control components and broaden them as necessary, particularly to integrate treatment for more than one NTD. Integration of NTD programmes also include parasitological surveys among others where two or more NTDs are assessed at the same time to determine their geographical and epidemiological distribution. The assessment for prevalence of schistosomiasis, in most instances, are conducted together with that of soil transmitted helminthiasis, trachoma and or lymphatic filariasis (Hodges et al., 2012). Integration of NTD interventions including health education, WASH and treatment is also encouraged for cost effectiveness and sustainability of programmes (Fitzpatrick et al., 2017).

4.2.1 Schistosomiasis

Schistosomiasis, bilharzia, or snail fever is a common preventive chemotherapy neglected tropical diseases (NTDs) highly endemic in the tropics and subtropical areas (Gabrielli et al., 2011). In line with the World Health Organisation's ambition, there is a global vision to have a future world free from schistosomiasis with three major goals to control morbidity by 2020, eliminate schistosomiasis as a public health problem by 2025 and to interrupt transmission of schistosomiasis in the Region of the Americas, the Eastern Mediterranean Region, the European Region, the South-East Asia Region and the Western Pacific Region, and in selected countries of the African Region by 2025 (World Health Organization, 2012a). Schistosomiasis was declared a public health problem from the inception of WHO in 1948, with several subsequent resolutions on the disease, the most recent in 2013 on control and elimination passed during the 65th World Health Assembly (World Health Organization, 2012c).

Historical research in Zambia has shown endemicity of schistosomiasis since the early 20th century and the risk was estimated between 2.0% and 99.6%. Low endemic areas were found in northern Zambia with smaller low endemicity areas

located in the centre of the country. Highly endemic regions were distributed throughout Zambia with some larger clusters in the North and East (Buckley, 1946). Cross sectional and experimental studies on parasitological and snail biology in Lakes Kariba and Bangweulu and Lusaka district conducted in 2002 showed *S. haematobium* infection prevalence was 0% around Lake Bangweulu and 76% around Lake Kariba and the snails were compatible with all strains of *S. haematobium* collected and tested from different areas .

To explore the differences in the prevalence and intensities of *S.haematobium* and *S. mansoni* transmission in Lake Kariba and Siavonga, a longitudinal study was conducted in 2003 and results showed prevalence of *S. haematobium* and *S. mansoni* infection among school children in Siavonga was 19.4% and 33.5%, respectively which was lower than that observed in Lake Kariba separated by a distance of 10 km. Better water and sanitation facilities were observedto be the major factor for reduced prevalence of schistosomiasis in Kariba comparedto Siavonga (Chimbari et al., 2003). Schur estimated the country-specific prevalenceof schistosomiasis in school-aged children in Zambia at 25.9%, classifying the country as moderately endemic with no switch in endemicity at province level but district level where it ranged from low (Luwingu and Mporokoso) to high endemicity(Chama, Chililabombwe, and Lundazi) (Schur et al., 2012).

With regards to risk factors and spatial heterogenicity in disease prevalence, in 2008 Simoonga conducted a small-scale cross-sectional study in Lusaka district which focused on socio-demographics, parasitological and climatic factors and found the risk factors to be geographical location, altitude, normalized difference vegetation index, maximum temperature, age, sex of the child and snail abundance. The mean prevalence rate was 9.6%. and infection risk was highly correlated with host snail abundance and vegetation cover (Monde et al., 2016). However, less than 30% of the population were aware of the risk factors and the existence of the parasite and use of contaminated water was the major risk factor (Simoonga et al., 2008).

An annualised treatment estimates needs of 1.1 to 1.2 million by the bilharzia control programme was based on the aggregation level of schistosomiasis prevalence (unpublished report). A more comprehensive effort to record the distribution of these diseases was undertaken in 2005-2007 with support from the Schistosomiasis Control

Initiative (SCI), London. These results helped to generate more general predictive maps that projected an estimate of 2.5 million people to be affected in Zambia which was a first attempt to estimate large scale treatment needs (Clements, 2005). Later studies assessed the spatial heterogeneity in risk of infection at a micro-geographical level and the quantification of such small-scale heterogeneities in targeting control initiatives (Simoonga et al., 2008), but these did not address the disease burden at national scale. Indeed, the focal nature of schistosomiasis often contributes to low non-significant prevalence when larger areas are examined. This is typical as substantial variation in exposure to schistosomiasis, even within endemic communities as reported in Brazil (Barbosa et al., 2006) and in China (Wang et al., 2008). In Zambia, the 2005 study by SCI had low geographical coverage meaning that many locally infected communities were not sampled (Clements, 2005).

With recent changes in agriculture and urbanisation there is a pressing need to update and expand the national surveillance for schistosomiasis, which may also impact differentially on each species of schistosome. In 2010 Agnew-Blais assessed the prevalence and risk factors associated with *S. haematobium* infections revealed that peri-urban populations had a significant but under-recognised vulnerability to infection, and suggest that history and physical examination that is usually performed is inadequate to identify areas requiring population-based control programmes (Agnew-Blais et al., 2010).

Schistosomiasis is a major cause of morbidity and mortality affecting a lot of people in the marginalised communities of Zambia. It causes acute and chronic conditions that usually go undiagnosed especially in the remote parts of the country. Strahen in 2012 evaluated the prevalence of *S. mansoni* related liver disease in school-aged-children along the Zambezi river in Chitokoloki district on the western part of Zambia. 37.2 % of the 41 participants in this observational cross-sectional study were observed to peri-portal fibrosis and four children at risk of advanced fibrosis. A year later Payne administered a symptom questionnaire and conducted a demographic survey and physical examination amongst patients presenting to Kaoma district outpatient clinics in the western part of Zambia and assessed the prevalence of *S. mansoni* infections using Enzyme linked immunosorbent assay (ELISA) and found very heavy burden of schistosomiasis-related portal hypertension (Payne et al.,

2013). The children in all the studies had relatively high prevalence of *S. mansoni* with related liver disease that required urgent and prompt treatment. Schistosomiasis pulmonary arterial hypertension is another condition that has been observed in Zambia (Sibomana et al., 2020). The evidence is a call for mass treatment in these affected parts of the country to address and prevent extensive pathology of hepatosplenic schistosomiasis. Safe water and health education throughout the affected countries are clearly also important.

Much earlier in 2005, Clements conducted an epidemiological analysis of schistosomiasis in 80 schools from Eastern and Southern Province which he used to demonstrate a generally high prevalence of *S. haematobium* throughout the country as shown in Figures 4-1 A-B. Based on the predictions in Figure 4-1, it was recommended that areas outside of Southern and Lusaka provinces equally had similar infection on the basis of this map. However, the map for *S. mansoni* showed a generally low prevalence, with intervention areas restricted to the Luangwa and Zambezi river valleys. Predictive maps are often unreliable in terms of monitoring as it is based on assumption of possible presence of infection or transmission. More studies were required to come up with a clear picture of endemicity and prevalence. It is also unclear how much treatment has occurred since then and whether any reductions in disease caused by the initial MDA have been maintained.

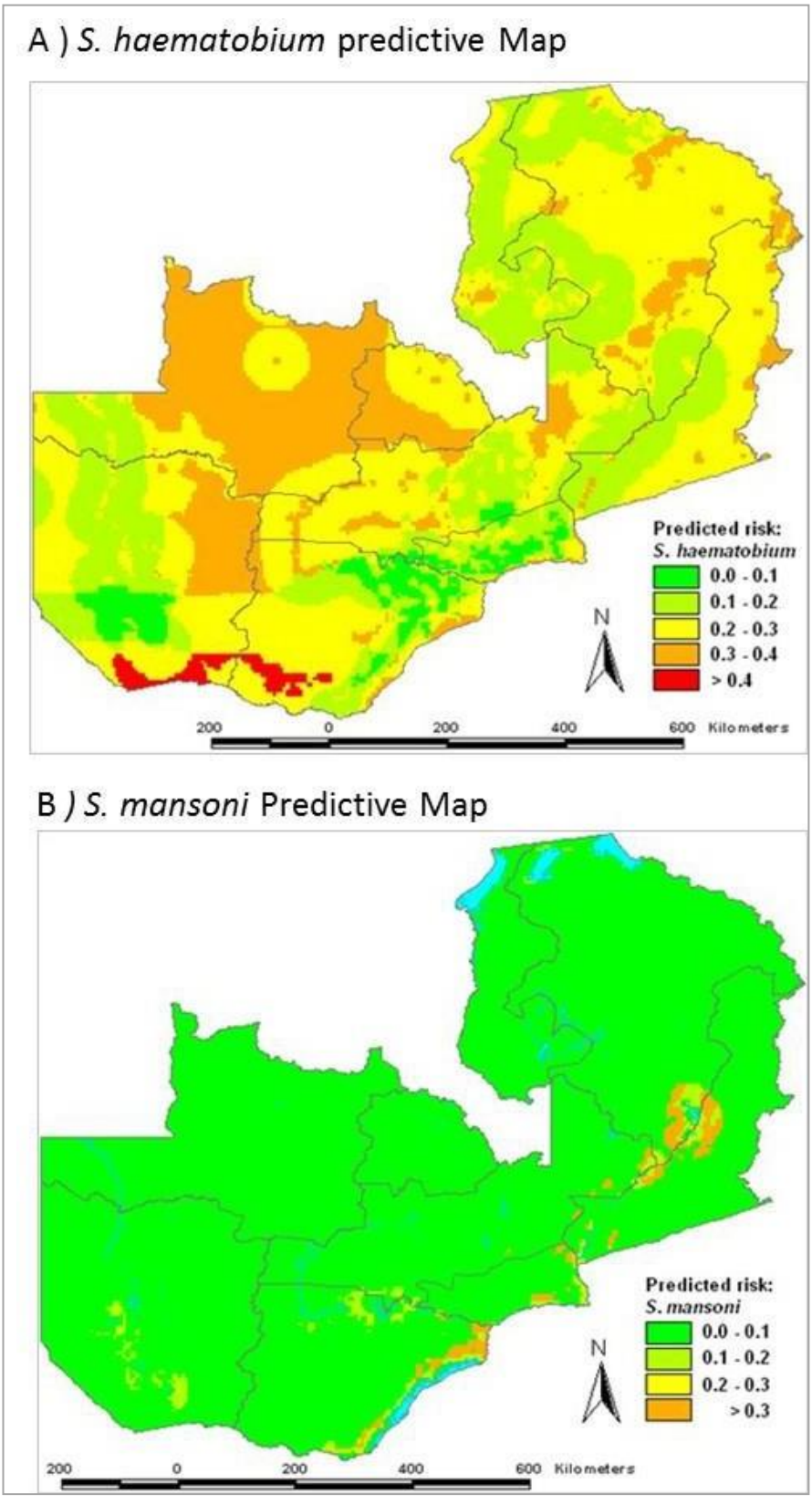


Figure 4-1 Risk for *S. haematobium and S. mansoni* infection in Zambia based on a traditional logistic regression model.

Lusaka province in both maps show that the predicted risk of both species is very low and that generally *S. mansoni* was very low in most parts of the country (Clements, 2005)

In order to compile comprehensive information on the prevalence of schistosomiasis in Zambia and enhance the knowledge of spatial distribution to assist planning of the longitudinal monitoring using baseline data that this research will provide; further detailed mapping was essential and at a much finer level of spatial resolution. This data on the prevalence of schistosomiasis, affected populations living in endemic areas, the environmental factors impacting on schistosomiasis distribution/endemicity and endemicity risk in Zambia will be presented in this chapter. The data collected were a critical, first step in providing a more developed understanding where at risk populations reside. This was specifically to target available control resources effectively and to achieve a maximum future impact on the disease burden with preventive chemotherapy regimens. Table 4-1 below provides the recommended treatment strategy for schistosomiasis.

Table 4-1 Recommended treatment strategy for schistosomiasis in preventive chemotherapy

Note. in high risk areas treatment for SCH is in all children in that implementation unit and all the adults at risk, while moderate risk communities children are treated every other year together with the groups at risk and in low risk areas children are treated twice during the primary school education (Gabrielli et al., 2011)

Category	Prevalence among school-aged children	Action to be undertaken	
High-risk community	≥50% by parasitological methods (intestinal and urinary schistosomiasis) or ≥30% by questionnaire for visible haematuria (urinary schistosomiasis)	Treat all school-aged children	Also treat adults considered to beat risk from special groups (e.g. fishermen) to entire communities
Moderate-risk community	≥10% but <50% by parasitological methods (intestinal and urinary schistosomiasis) or <30% by questionnaire for visible haematuria (urinary schistosomiasis)	Treat all school-age children (enrolled and not enrolled) once every 2 years	Also treat special risk groups only.
Low-risk community	<10% by parasitological methods (intestinal and urinary schistosomiasis	Treat all school-aged children (enrolled and not enrolled) twice during their primary schooling age (e.g. at entry and exit)	Praziquantel should be available in dispensaries and clinics for treatment of suspected cases

4.2.2 Soil transmitted helminthiasis

Soil-transmitted helminthiasis (STH) are parasitic infections caused by nematode species that commonly affect communities with poor sanitation and living conditions. Like LF and schistosomiasis, they also form part of the neglected tropical diseases that usually affect the poor and marginalised communities where there is poverty, poor environmental hygiene and impoverished health services (Montresor, 1998). There are three main parasites endemic and prioritised in Zambia. These include *Ascaris lumbricoides,* hookworms and *Trichuris trichiura*. More information on STH is described in chapter two of this thesis. Morbidity from STH is relatively easy to control and WHO has provided guidelines on effective ways of preventing and controlling STH (Gabrielli et al., 2011). However, multisector approach to implement a comprehensive strategy in order to eliminate STH is critical. The strategy comprises of five interventions namely preventive chemotherapy, hygiene practices, and access to clean safe water, improved sanitation and health education on STH abbreviated as PHASE strategy.

In 2001, during the World Health Assembly, a resolution WHO54.19 was passed to regularly treat at least 75% of school-aged children in all endemic countries at risk of morbidity (World Health Organization, 2001). This has been a challenge to achieve and only 13 % of the all endemic countries reached the target in 2011 (Olds, 2013), 52 % in 2015, 70% in 2017 and 60% in 2018 (Montresor et al., 2020) while in the African region where 46 countries are endemic but only 17 reached the 75% treatment coverage in 2007 and 18 countries in 2008, the overall coverage has 15% in 2008, 22% in 2011, 50% in 2013, 68% in 2016 and 60% in 2018 (Montresor et al., 2020). This has been increasing and in 2017, 28 countries treated for STH though only 22 reached the 75% target. The evidence about control of infection and break in transmission can be achieved with regular treatments in school aged children based on available evidence (Gabrielli et al., 2011). In the 1993 World Bank Report, STH ranked first among children aged 5-14 years and DALYS were lost which represented 11.7%of the total burden of this age group (World Health Organization, 2005, Musgrove, 1993). Controlling of the infections was cost effective and efficient and 70% of the infections could be prevented by treating school aged children in high prevalent areas (Gabrielli et al., 2011, World Health Organization, 2013g). Infection

from *T. trichiura* and *A. lumbricoides* reach its peak in this age group but hookworm can also be very high in adulthood (World Health Organization, 2005).

Historical research in Zambia has shown that STH has been endemic since the early 20th century and widespread with *T. trichiura* being less frequent (0.3%), *A. lumbricoides* (3.7%) and hookworms (52.2%) more common (Buckley, 1946). Soil transmitted helminthiasis is a major cause of infection and morbidity which affects many Zambians living in marginalised communities. The communities are aware that STH cause loss of weight, abdominal pain, anaemia and children look weak but consider it a natural thing to happen in their lives because every child will be infected at one time and usually did not die from it unlike malaria (Halwindi et al., 2015). However, some communities know exactly what the risk factors are including eating contaminated fruits and vegetables, putting contaminated hands in the mouth, eating soil and drinking contaminated water.

Zambia plans to step up the fight against STH through prevention of infection, control and reduction of morbidity through primary health care, community health and health promotion and education (Ministry of Health, 2016). STH are amenable to preventive chemotherapy, a public health intervention strategy that focusses on large-scale administration of safe and effective medicines to affected populations. Mass deworming targets under-five children, pregnant women and school aged children. The NTD programme focuses on school aged children while medicine is administered to pregnant mothers through antenatal clinics and to children below the age of five during child health clinics and outreach activities (Montresor et al., 2020, World Health Organization, 2013g). In Zambia like many African countries, most of the deworming is highest in the under-five compared to school aged children (World Health Organization, 2017a), despite the later having the highest worm infestation (World Health Organization, 2005).

The benefits of deworming children are great including child development through improved health and education of children and the most disadvantaged children, such as girls and the poor, often suffer most from ill health and malnutrition, and gain the most benefit from deworming (World Health Organization, 2005). Highest treatment coverages (epidemiological, programmatic and geographical) are likely if the health workers empower and engage the communities for Community

Directed Treatment approach using the community drug distributors as evidenced by earlier studies that observed that community participation in decision-making was positively associated with treatment coverage and was predictive of sustainability of Community Directed Treatment (Silumbwe et al., 2019, World Health Organization, 2012a, World Health Organization, 2013g) and the door-to-door campaigns even though more costly, produce better coverage than central place approach (Halwindi et al., 2011, Halwindi et al., 2013). Effective implementation of these will also contribute to the health systems strengthening and universal health coverage without leaving anyone behind. This will reflect what has been outlined in the Zambian Seventh National Development Plan under the theme "accelerating development efforts towards vision 2030 without leaving anyone behind" (Government of the Republic of Zambia, 2017b), where tackling NTDs in Zambia will contribute to developmental and economic gains. By addressing the problem of NTDs the vicious cycle of NTDs and poverty maybe broken. However, this will require addressing the other contributing factors towards NTDs and STH in particular such as water, hygienic, environment and sanitation. By so doing the Zambian health systems will be strengthened and there will be universal health coverage for NTDs.

Baseline information on the disease burden is important for any disease control programme. Hookworms, *A. lumbricoides* and *T. trichiura* are widely spread at high levels across the country but there is inadequate evidence to support this statement. Sporadic studies have been done in various parts of the country but not at national scale. Previous mapping surveys by Zambia Bilharzia Control Programme and Clements produced predictive risk maps confirming the presence of STH in the country (Clements, 2005) but the surveys were concentrated in Eastern and Southern parts of the country as shown in Figure 4-2 A-C. It is necessary to synthesise information to be able to implement interventions that are evidence based and cover the whole nation.

However, most of the available data are more than 10 years old and according to WHO guidelines data for development of control programme should be less than 10 years. In addition, Zambia had never conducted a nationwide survey for STH and SCH. Therefore, Zambia needed reliable information on the geographic distribution to inform policy and planning and guide the national control programme. The

evidence produced will inform the Ministry of Health where control and elimination interventions should be implemented, including areas for multisectoral approaches. This chapter presents the prevalence assessment of schistosomiasis and soil transmitted helminthiasis in Zambia.

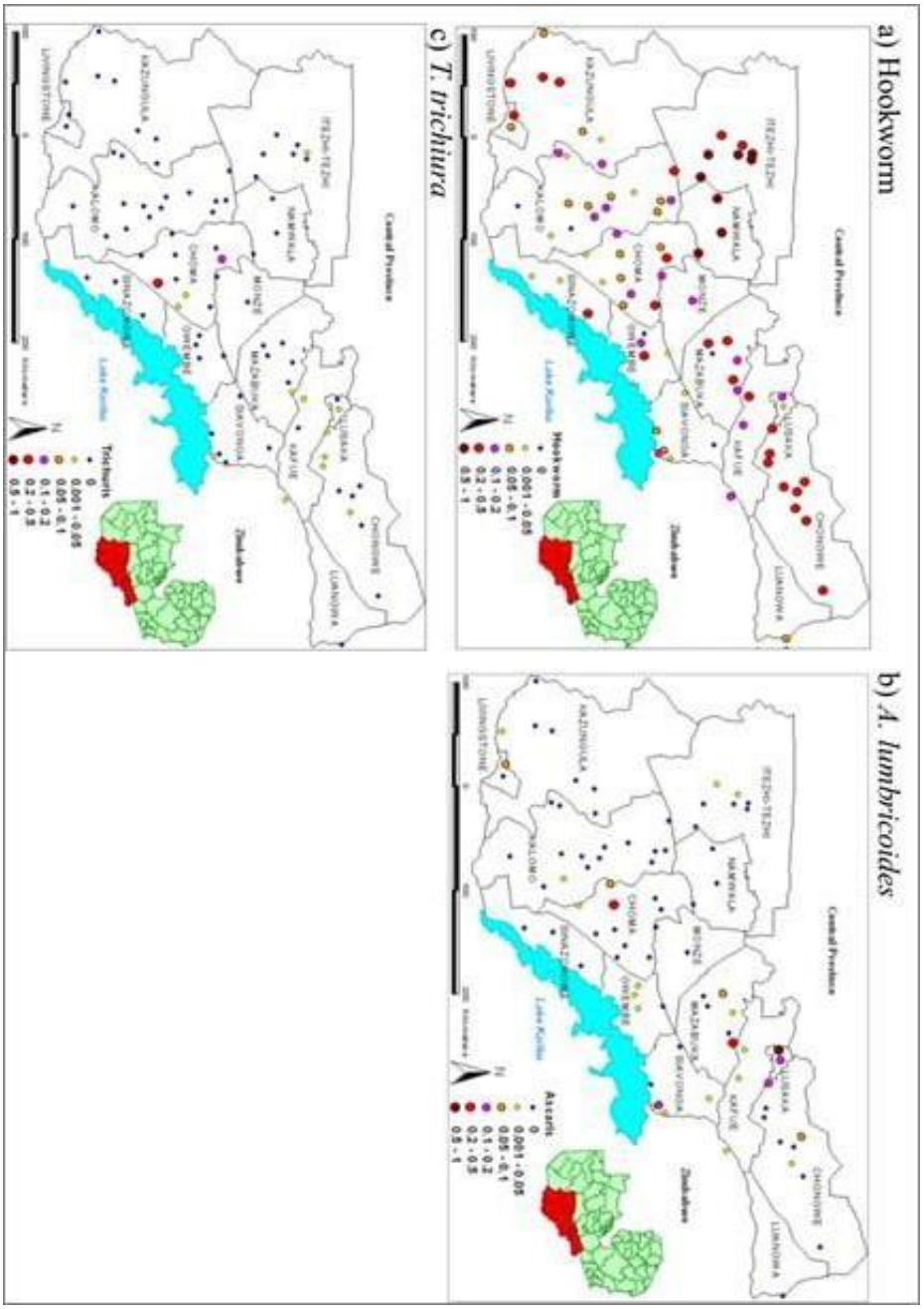


Figure 4-2 Observed prevalence of a) Hookworm, b) *Ascaris lumbricoides* and c) *Trichuris trichiura*

The data presented in the maps is from 143 schools in Southern Zambia (Clements, 2005)

4.3 Overall Aims and Specific Objectives

The overall aim of this chapter is to assess the demographical and environmental factors contributing to the distribution of schistosomiasis (urogenital and intestinal schistosomiasis) and Soil transmitted helminthiasis in Zambia and analysis of the treatment requirements. This was conducted under three sections as follows:

4.3.1 Provincial and district level: distribution and demographics

i) To define and map provincial and district prevalence rate for:

- *S. haematobium* foci
- *S. mansoni* foci
- Schistosomiasis
- *A. lumbricoides* foci
- Hookworm foci
- *T. trichiura* foci
- Overall STH

ii) To assess co-endemicity and produce maps for schistosomiasis and soil transmitted helminthiasis

iii) To assess the demographical factors associated with the distribution of schistosomiasis and soil transmitted helminthiasis at provincial and districts levels.

4.3.2 School level: spatial and environmental analysis

i) To determine spatial patterns of school level prevalence and identify high risk clustering.

ii) To identify the environmental factors associated with the distribution of schistosomiasis and soil transmitted helminthiasis

4.3.3 Actionable insight to guide schistosomiasis and soil transmitted helminthiasis programmatic roadmap

i) To assess the effect of the geographical scale of schistosomiasis and soil transmitted helminthiasis risk estimates on the amount of praziquantel and albendazole or mebendazole treatment needed, respectively, in the school-aged population in Zambia

ii) To estimate the at-risk population of school-age children requiring integrated schistosomiasis/soil-transmitted helminth treatment regimens according to the co-distribution

iii) To predict and forecast praziquantel and albendazole/mebendazole treatment needs to secure necessary supplies through time.

4.4 Methods

4.4.1 Study design

A cross-sectional school-based quantitative study was conducted from March 2012 to April 2013.

4.4.2 Study area, site selection and sample size

Zambia is administratively divided into 10 provinces, which at the time of the study were further divided into 72 districts. All the districts were included in the study as there was no available comprehensive prevalence rate data for the entire country. Site (school) selection was random for the first four provinces whilst for the other six provinces it was purposefully done in consultation with the district (both health and education offices) based on the ecology, but both ensured that all the zones in the district were covered. The study targeted school aged children between 10-14 years, 30 pupils per school (balanced by gender, 15 girls and 15 boys) and 20 schools per district (4 schools per Zone – Central, East, West, South and North). Sampling: To arrive at the sample size, we used the WHO guidelines on how to calculate sample size for control measures (Montresor, 1998). Therefore, to calculate the sample size we used the following sample size calculation from the WHO practical manual for sample size determination in health studies (Lwanga, 1991) in the equation below. A measure of how close this estimate is to the true value of a population parameter was

put at an absolute 4 percentage point with 95% confidence at an anticipated population proportion of 50%.

Anticipated population proportion = P

Confidence level = 100(1-1x) %

Absolute precision required on either side of the proportion (in percentage points) = d

P=50% or 0.5

CI=95%

d =0.04

$$n=Z^{2}_{1-x/2}P(1-P)\,d^{2}$$

=600

WHO guides that in an ecologically homogenous area in order to evaluate prevalence, for control measures, 200-250 individuals should be adequate, but where climatic and ecological zones are different a further 200-250 individuals should be sampled. The sample size calculated of 600 is more than adequate to get an absolute precision.

Each pupil provided both stool and urine specimen for examination (Figure 4-3). One stool and one urine sample per child is considered enough for mapping. If a child cannot provide both urine and stool samples, he/she was replaced by another child.

4.4.3 Field survey methodology

The study comprised of 6 teams. Each team had a supervisor (laboratory technologist, or an experienced laboratory technician), 2 laboratory technician and social mobiliser. Prior to the mapping exercise, the teams were oriented on the protocol, the study objectives, and the expected outcomes before going out in the field. A detailed field work plan was developed based on the teams created and districts the provinces they were conducting the study. The laboratory technicians came from the University Teaching Hospital and the University of Zambia (School of Medicine and School of Veterinary medicine). Additional staff was obtained at district level to assist in the laboratory and field work. This was also to sensitise andbuild capacity on the NTD study, why it was being conducted in addition to

empowering the local community. A letter was also written to the local authorities introducing the nationwide surveys for schistosomiasis and soil transmitted helminthiasis. Before the survey teams went out into the field, I ensured each team had adequate materials and resources to cover the period in the field. The local health personnel led the study teams to the selected schools. The GPS coordinates for the sampled schools were also recorded using handheld GPS receivers (e-trex, Garmin, USA). Children aged between 10 and 14 years were randomly selected.

Data were collected and recorded first using paper forms (see annex). Upon arrival at a school site details were recorded which included date, community/village/city name, district name and code, provincial name and theinitials for the team leader. The second section was for recording the GPS coordinates, third section was school details (name, code, name and contact of headteacher, recent treatment at the school) and the last section was school enrolment. Inaddition to this form was a form for the pupil which captured the school name and code, pupil's ID, sex, age and results urine and stool samples. The completed formswere collected and stored by the supervisor at the end of each day. Any missing datawas identified before leaving the site was obtained. At the end of the field visits all the data collected was entered at national level, cleaned by removing duplicates, wrong data, incomplete/missing site and pupil information. The individual data wasthen put in a Table for aggregation at each level, school level, district level and provincial level and was then used to calculate the prevalence at each level. This wasdone for all the five species (two SCH and three STH and the combined prevalence).The clean data and reports were forwarded to LSTM for further data generation. Thedata was then analysed to produce initial reports

For each stool collected, Kato Katz was used to look for eggs and for urine, eggs from urine filtration viewed by microscopy (x100) for magnification and identification. I looked for the hookworm eggs within 30 minutes of preparing the slides and the rest of the eggs for the other species within 24 hours of preparing the slides. A simple presence/absence test was used for the mapping activities. The Kato-Katz procedure provided a prevalence estimate for each mapping unit that would be enough to classify the mapping units into non-endemic, low, moderate, or high risk for intestinal schistosomiasis (*S. mansoni)*, and STH. The indicator for intestinal

schistosomiasis and STH was the presence of eggs in stool samples. The indicator for urinary schistosomiasis (*S. haematobium*) was the presence of haematuria using a Dipstick and schistosome eggs in urine samples obtained from urine Filtration. Urine sample testing for presence of eggs was processed and examined later in the day at the setup field laboratory.

During the field work, I checked the forms for completeness for the team I worked with and collaborated with the other teams for daily updates. I worked with the laboratory technicians and prepared some slides and confirmed any presence or absence of the parasite eggs. Before moving to another school, I gave a report of the findings to the head teacher and treated all the children that participated in the survey.

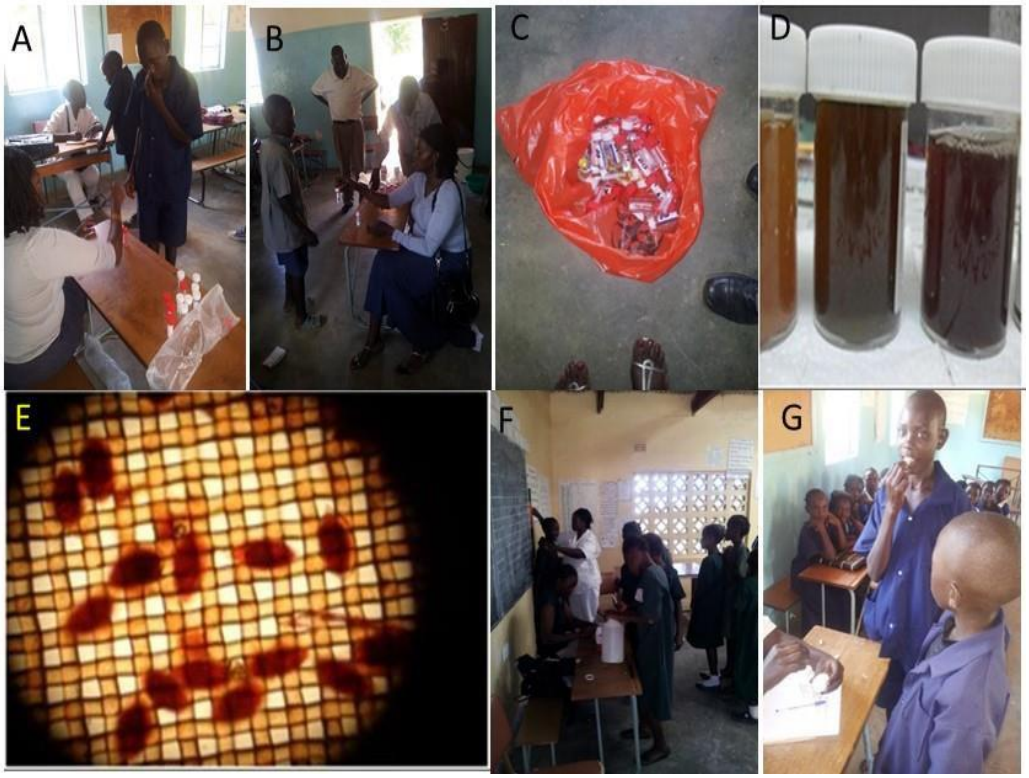


Figure 4-3 Pictures taken during the study field work

a) sampling of school aged children b) & c) correct labelling of specimen bottles and giving instructions to pupils on how to use the two different bottles to collect stool and urine d) & e) samples of the urine specimen collected f) schistosome ova seen under a microscope g) children that participated in the survey receiving praziquantel Tablets.

4.4.4 Data analysis

Provincial and district level: distribution and demographics

4.4.4.1 **Define and map the provincial and district prevalence rates**

Data was captured on data collection forms designed for the study. The data were entered in Microsoft Excel and cleaned. Descriptive analyses used IBM Statistical Package for Social Science Version 26.0 (IBM SPSS 26), and the map production using ArcGIS (ESRI, California, and the USA). The prevalence was then used to classify the site and district levels into the WHO endemicity categories by parasitological methods of low risk (<10%), moderate risk (≥10% but <50%) and high risk (≥50%) for SCH and <20% low risk for STH.

4.4.4.2 **To assess the demographical factors associated with the distribution of schistosomiasis and soil transmitted helminthiasis**

The descriptive analysis includes socio-demographic characteristics and epidemiological distribution of SCH and STH, determination of the proportion of the test result by sex, age-group, and for continuous variable like age, I computed mean, median, mode, range and standard deviation; while, for categorical variable such as province, districts, gender and age group run frequency distribution.

Crosstabs descriptive was used to test whether the difference in age group and sex to infection occurred by chance or was statistically different. Another analysis was performed to test whether the observed frequencies were statistically different from the expected frequencies for Urine filtration and dipstick results. A Pearson Chi-Square test was performed to test the Null Hypothesis that observed frequencies are statistically different from the expected frequencies. To determine the relationship between the two test types, a Phi and Cramer's test was performed for association. This was further proved by the verification with a Pearson Correlation by conducting a bivariant correlation on the two test variables.

4.4.4.3 **To determine spatial patterns of school level prevalence and identify high risk clustering at a finer scale**

In order to determine the spatial patterns of school level prevalence and identify risk clustering at a finer scale, the coordinates of the sample sites documented using GPS were used. Prevalence maps of geographical distribution of each disease using observed point prevalence from each school were produced using QGIS map

software. High risk and low risk clustering were determined using ArcGIS spatial analysis tool and the Getis Ord statistic for hotspot analysis.

Hot spot analysis is calculated using this formula

$$Gi^{*}=\sum_{j=1}^{n} Wij - X\sum_{j=1}^{n} Wij \Big/ \frac{}{S\sqrt{\int n\sum_{j=1}^{n} Wi\ \ j - [\sum_{j=1}^{n} Wij]^{2}}\ \ \}}$$

Key: xj is the attributable value for feature j

w,j is the spatial weight between feature i and j

n is equal to the number of features

S is the sample variance

Source: (Getis, 1992)

4.4.4.4 To identify the environmental factors associated with the distribution of schistosomiasis and soil transmitted helminthiasis

To examine environmental factors associated with the distribution of Schistosomiasis (urogenital and intestinal schistosomiasis) and soil transmitted helminthiasis (intestinal helminthiasis) four main variables were examined

Elevation in metres (m)

Precipitation in millimetre (mm)

Temperature in ℃

Soil fractions in mean values at 5 cm

The raster data were extracted from National Aeronautics and Space Administration (NASA) Shuttle Radar Topography Mission (SRTM) for elevation. The study used the elevation bands of 1000m. Elevation data used in the image were acquired by the SRTM aboard the Space Shuttle Endeavour. The data were processed into geographic "tiles," each of which represents one by one degree of latitude and longitude. A degree of latitude measures 111 kilometres (69 miles) north-south, and a degree of longitude measures 111 kilometres or less east-west, decreasing away from the

equator and Africa has 3256 tiles segments, almost a quarter of the total data set. Statistical analysis to determine the mean for each altitude in meters was performed using zonal statistics in QGIS. The precipitation and temperature data were obtained from World Climate data downloaded from available website - http://www.worldclim.org/. Worldclim is modelled environmental data available for ecological niche modelling which is based on 30 years of data. The grid data covers the global land areas in geodetic coordinate system. The spatial resolutions used was 30 seconds. The predictors tested from worldclim included annual mean temperature, minimum temperature of coldest month, maximum temperature warmest month, annual precipitation, precipitation wettest month and precipitation driest month. The grid data (raster) were imported into QGIS for statistical analysis and the soil types was obtained from The Africa Soil Information Service (AfSIS) available at ftp://africagrids.net/ and the top soil fractions were calculated as the mean values in soil were according to the standard depth (sd) intervals applied to all soil types as indicated at https://www.GlobalSoilMap.net/specifications at sd1: 0-5cm, sd2: 5-15cm sd3: 15-30 cm, sd4: 30-60 cm, sd5: 60-100 cm, and sd6: 100-200 cm. The soil types used in the analysis include sand, clay and silt in the topsoil. The PH for the topsoil was included in the analysis categorised as acidic, neutral, very acidic. The mean values of the rasters for the predictors of each implementation units were extracted using QGIS. The sets were then assembled with the aggregated data for *S. haematobium, S. mansoni*, *A. lumbricoides*, hookworm and *T. trichiura*. In order to explore associations between the prevalence of the 5 species and the environmental predictors, data were exported for analysis into excel Microsoft and scatter plots produced. Transformation was performed where there was no clear linear association by either using empirical log transformation:

Log (n +0.5)/(N-n+0.5)

where n is the number of children that tested positive for SCH and STH in a district; N is the total number surveyed per district

Or

Log10(species prevalence)

Or

X^2 where X is the prevalence of the species

For some variables, categorising them into three levels or more to show the association was done especially were a non-linear association was possible from the scatter plot. To test for correlation tests with the Null Hypothesis is 0. My study data is huge such that even weak correlations can be classified as significant. A multivariate model was created to assess risk of infection with adjustment for predictors (elevation, temperature, precipitation, and soil types). A linear general model with post Hoc tests (Turkey test), Post Hoc Multiple Comparisons for observed means and multivariate options was conducted to identify possible independent predictors for SCH and STH species was used. The threshold for significant level was 0.05. Pearson's Correlation was also performed to confirm the correlation association between the variable species prevalence with elevation, precipitation, soil types, and temperature. These analyses were performed using SPSS 26 for statistical analysis, associations with high and low risk areas.

4.4.4.5 To assess the effect of the geographical scale of schistosomiasis and soil transmitted helminthiasis risk estimates on the amount of praziquantel and albendazole or mebendazole treatment needed, respectively, in the school-aged population in Zambia

To assess the effect of the geographical scale of schistosomiasis and soil transmitted helminthiasis risk estimates on the amount of preventive chemotherapy needed we selected some districts not previously sampled but has predictive values to be highly endemic and the survey data where prevalence has been calculated. In contrast to existing treatment need calculations based on country prevalence estimates, we used spatially explicit, model-based schistosomiasis risk estimates at high spatial resolution. Our modelling framework includes uncertainty measures, and hence allows CIs to be determined around predicted treatment needs. These empirical estimates can capture potential small transmission hotspots within a country that are typical for schistosomiasis, as the disease is often focally distributed, and facilitate spatial aggregation of schistosomiasis risk at different geographical scales. To determine the population at-risk and that requiring treatment schistosomiasis was based on model-based schistosomiasis risk estimates. The population at risk is the entire population in an endemic district that is likely to be exposed. The population requiring treatment was calculated using the WHO guidelines depending on the risk estimates based on endemicity status. For the high risk areas the population requiring

treatment under the NTD programme was calculated by taking the total populations for both SAC and adults (special groups pregnant and lactating mothers, those with occupation in infested water like the fishermen, farmers and irrigation workers) to the entire community, in the moderate risk areas half SAC and one third adult (special groups) populations was taken and in the low risk areas it was just a third of the SAC population that was calculated as the population requiring treatment (Stothard et al., 2013b, Gabrielli et al., 2011, Stothard et al., 2013a). Population data was obtained from the projections of the 2010 census for Zambia. The treatment strategy was determined using the WHO guidelines (Gabrielli et al., 2011). The analysis was performed in SPSS and the action maps produced using QGIS. Praziquantel treatment zones within schools were estimated by District, for either annual, biennial or entrance-exit mass drug administration campaigns. These aggregated data were compared against recent predictions from the WHO-preventive chemotherapy databank and will be used to optimise and refine drug forecasting. The tools will enhance planning and implementation of the schistosomiasis and soil transmitted helminthiasis control programme

4.4.4.6 **To predict and forecast the praziquantel treatment need**

To forecast medicines consumption for each year, data based on the risk estimates was used for analysis. The number of targeted people based on the 2010 census projections for the next five years was used and converted into estimates of quantities of medicines based on the WHO standardised algorithms (Gabrielli et al., 2011). With the forecasted consumption for each year of the quantification done the total estimated quantity required of each medicine was obtained.

4.4.5 Ethical consideration

Ethical approval was obtained from the Research and Ethics Committee of the national Ministry of Health, the university of Zambia and the University of Liverpool. Consent was obtained from the headteachers, and assent from the children examined. All positive cases found during the study were treated with praziquantel 20 mg/kg single dose for schistosomiasis and mebendazole 500mg for STH.

4.5 Results

4.5.1 Provincial and district level: distribution of schistosomiasis and sol transmitted helminthiasis

4.5.1.1 Distribution of schistosomiasis at National and Provincial levels

S. haematobium

The study was conducted in all 72 districts in the 10 provinces of Zambia and of the 43, 200 individuals targeted, 39,904 individuals were sampled between the ages of 3-27 years old. There was an equal proportion of the males and females sampled from primary and basic schools as shown in Table 4-4. The national prevalence of *S. haematobium* was found to be 14.6 %, and the provincial prevalence rates ranged from 2.4 % to 65.3%. Lusaka had significantly high prevalence with the confidence interval for *S. haematobium* above the national mean prevalence. The lowest prevalence was recorded on the Copperbelt (2.4 %), Northern (3.4 %) and Western Province 4.2 %) as indicated in Table 4-3. Lusaka was found to have significantly higher rates than all other provinces as shown in Figure 4-4 and 4-5. The next 2 highest provinces were Luapula (24.5%) and Northwestern (26.9%) which, although lower than Lusaka, were higher than the remaining 7 provinces.

Table 4-2 Summary Table of schistosomiasis species and co-infection provincial prevalence rates

Variable	Category	N	SH % *(CI_{95})*	SM % (*CI_{95})*	SCH % *(CI_{95})*	Co-infection *(CI_{95})*
Province	Central	4200	8.6	0.2	8.8	1.1
	Copperbelt	5295	2.4	0.2	2.6	0.7
	Eastern	3870	14.7	1	15.5	1.3
	Luapula	2981	24.5	0.8	25.2	0.8
	Lusaka	2378	65.3	1.1	65.3	1.5
	Muchinga	2546	16.9	1.9	20.3	1.9
	Northern	4917	3.4	1.1	6.2	5.3
	Northwestern	3568	26.9	9.8	28.6	6.8
	Southern	5484	11	4	14.3	4.6
	Western	3313	4.2	7.7	11.0	7.9
	National	38552	14.6	2.5	16.6	3.2

Table showing the prevalence of schistosomiasis species at provincial level in the study population

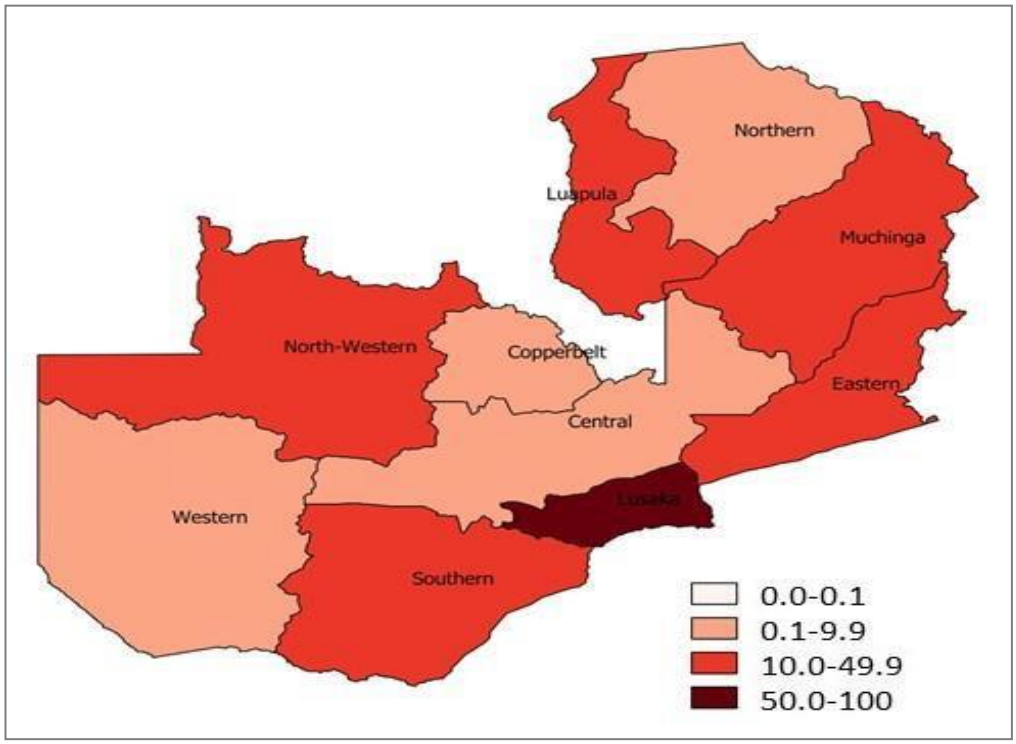


Figure 4-4 Map showing the provincial distribution of *S. haematobium* in Zambia

The map is showing moderate to high prevalence of *S. haematobium* in Zambia.

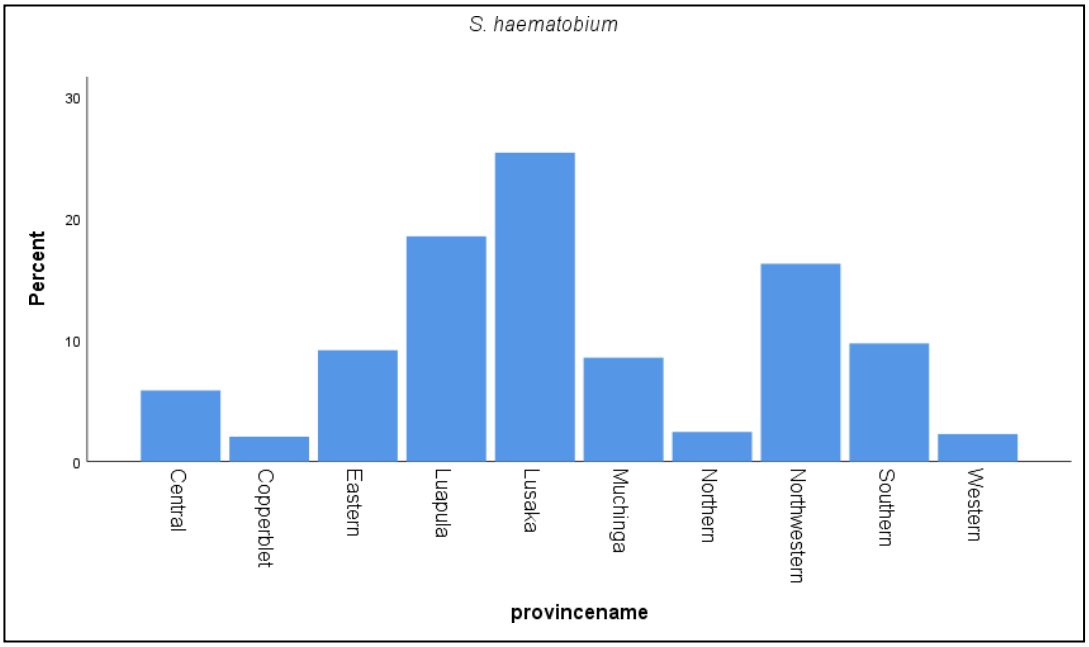


Figure 4-5 Graph showing provincial prevalence of S haematobium in Zambia

Lusaka Province has the highest prevalence followed by Northwestern and Luapula Provinces

S. mansoni

The national prevalence for *S. mansoni* was found to be 2.8%, and the provincial prevalence rates ranged from 0.2% to 9.8% with the lowest recorded on the Copperbelt and Central provinces at 0.2 % each, followed by Eastern Province (1.1 %) while the highest prevalence rate was found in Northwestern Province (9.8 %) followed by Western Province (7.7 %) and Southern Province (4.0 %) (Table 4-2). The map in Figure 4-6 indicates is a map showing the provincial prevalence rate ranging from 0.1 % to 9.8 %. Northwestern, though with a low prevalence was found to have significantly higher rates than all other provinces as shown in Figure 4-6 and 4-7.

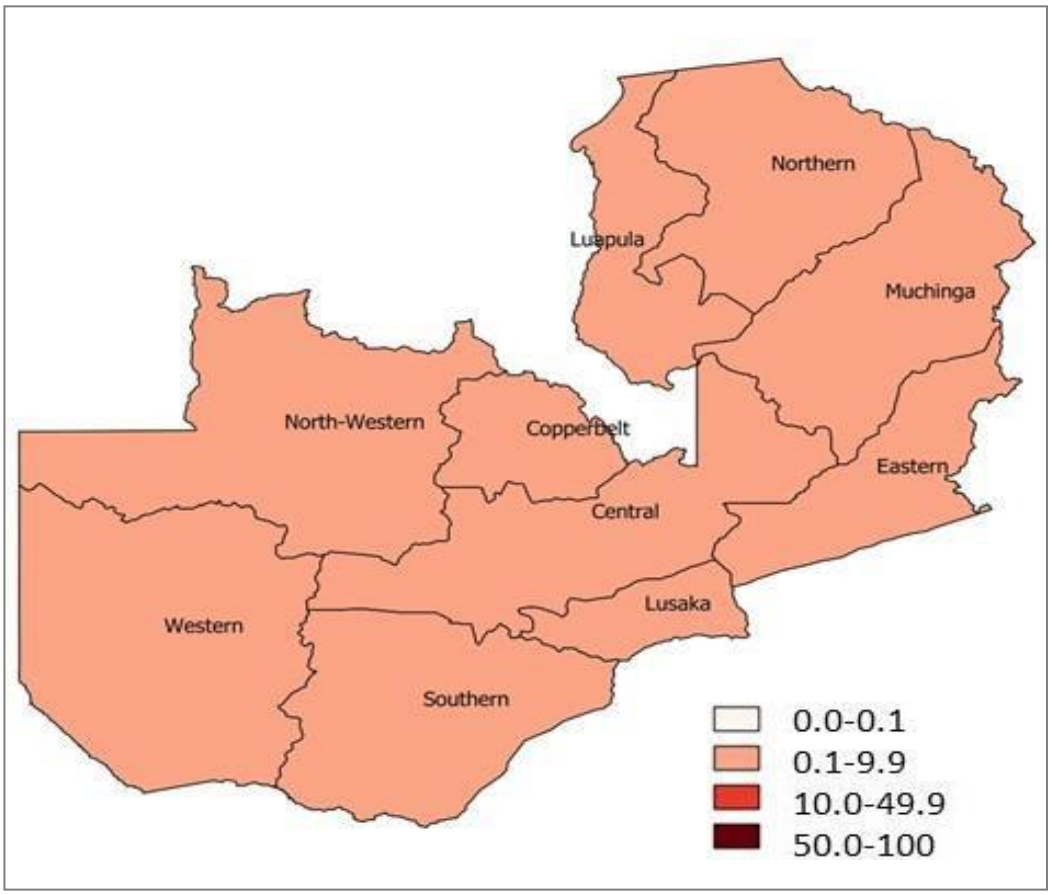


Figure 4-6 Map showing the Provincial distribution of *S. mansoni* in Zambia

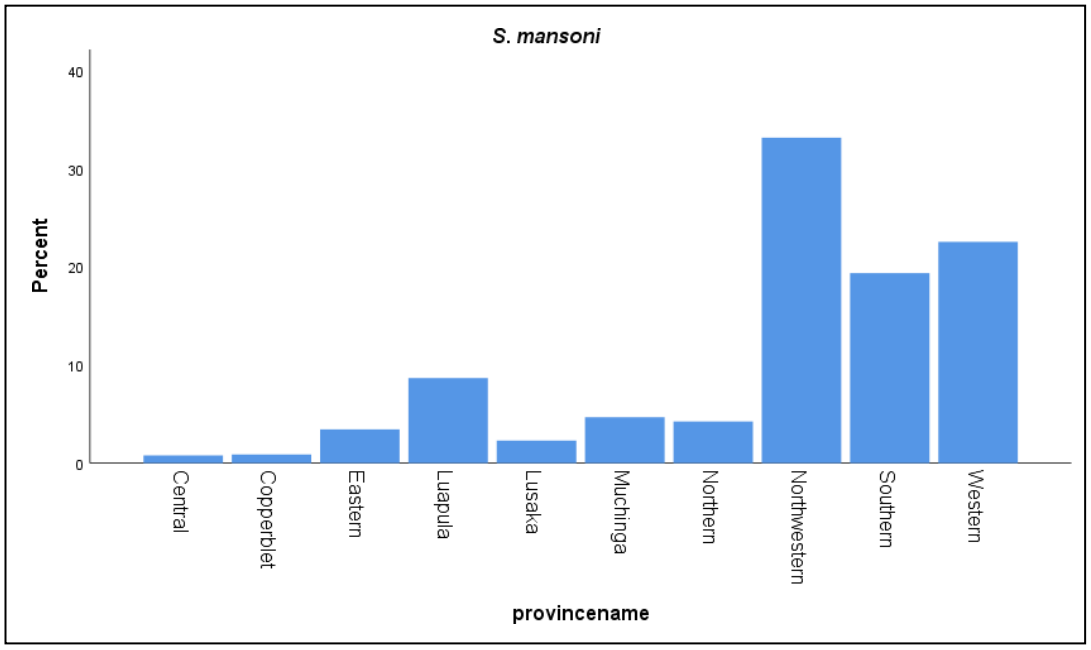


Figure 4-7 Graph showing the Provincial prevalence rate of *S. mansoni* in Zambia of the study population

The graph showing highest prevalence in Northwestern and Western Provinces

Overall schistosomiasis

Overall, the national prevalence of schistosomiasis (*haematobium* and *mansoni* combined) was found to be 17.4%, and the provincial prevalence rates ranged from 2.6 % to 65.3 % with the lowest and highest recorded on the Copperbelt and Lusaka Provinces respectively (Table 4-2). Lusaka was found to have significantly higher rates than all other provinces as shown in Figure 4-8 and 4-9. The next 2 highest provinces were Northwestern (28.6 %) and Luapula (25.6 %) which, although lower than Lusaka, were significantly higher than the remaining 7 provinces. Coinfection was found in 202 children which was 3.2 % of all the positive children. The highest province with co-infected children was Western Province (7.9 %) followed by Northwestern Province (6.8 %) and Northern (5.3 %). Only 0.7 % and 0.8 % of the positive cases were co-infected on the Copperbelt and Luapula, respectively, making them lowest.

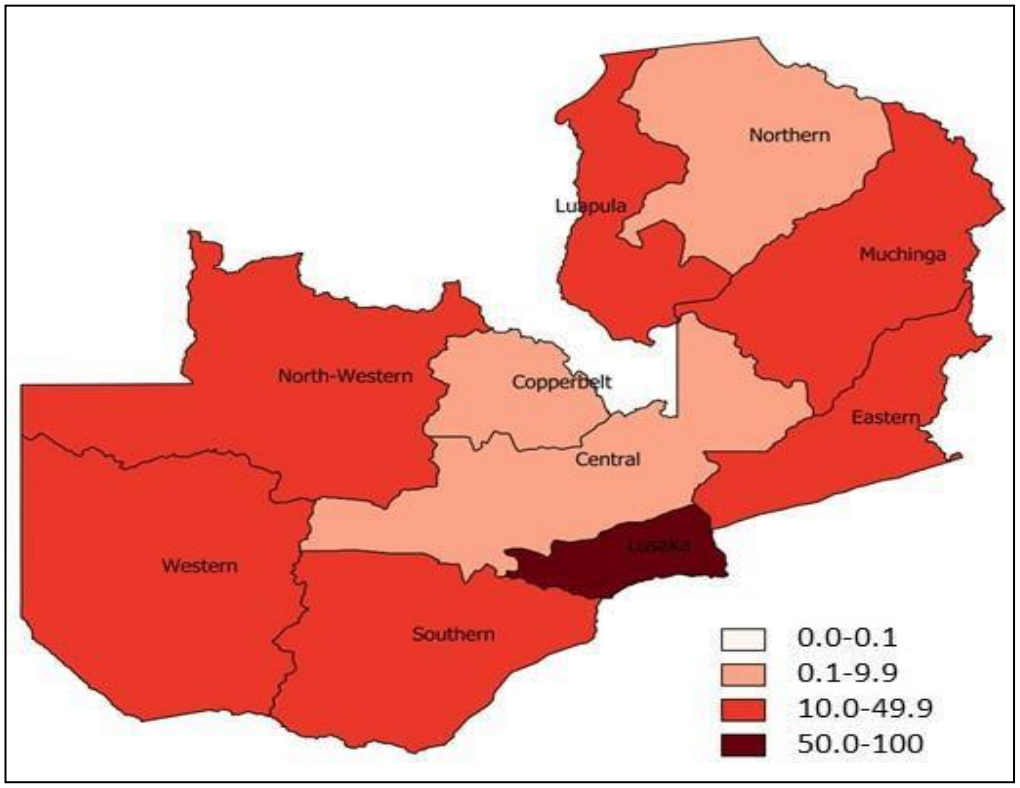


Figure 4-8 The map showing the Provincial distribution of schistosomiasis in Zambia

Lusaka province has the highest prevalence, six moderate and three low

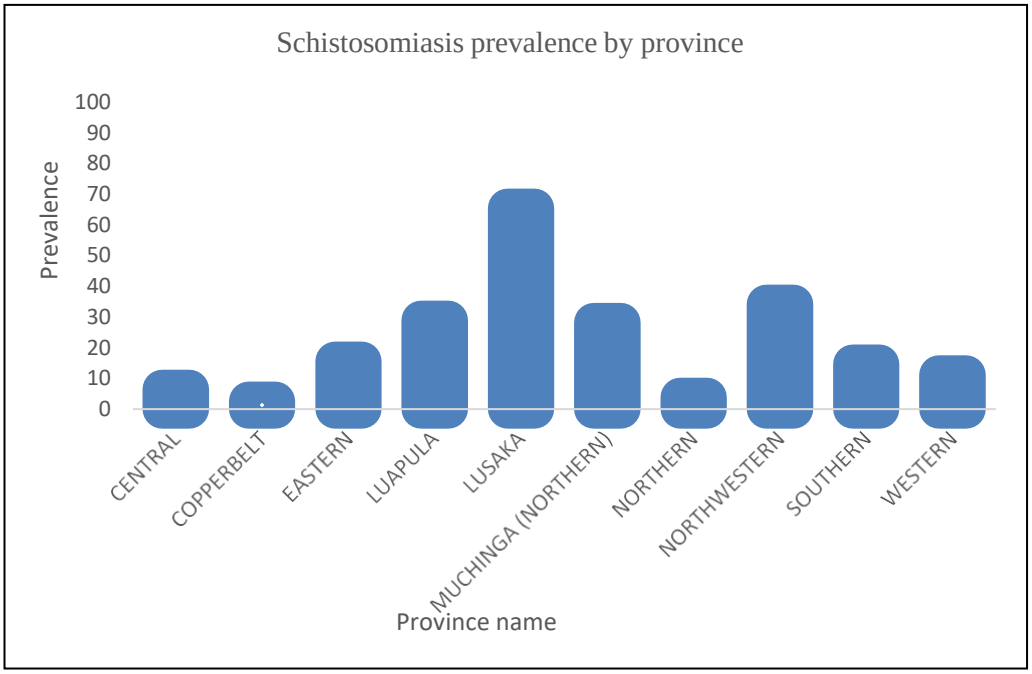


Figure 4-9 Graph showing the combined provincial prevalence for schistosomiasis

Highest prevalence is Lusaka followed by Northwestern and Luapula Provinces

4.5.1.2 Distribution of schistosomiasis at District levels

S. haematobium

At district level the prevalence rates ranged from 0 to 87.5% with the highest rates in Kafue (87.5%), Chongwe (78.7%) and Luangwa (67.8%) districts of Lusaka Province shown in Figures 4-10 and Appendix 3 Table 3, 9.7 % (7) of thedistricts had prevalence rates above 50 %. These were from Lusaka province (Kafue,Luangwa and chongwe), Northwestern Province (Mwinilunga and Kasempa), Luapula Province (Milenge) and Muchinga Province (Chama). 30 districts (41.7 %) had prevalence rand from 10 to 49.9 % and 32 districts (44.4 %) had prevalence ratesfrom 0.1 to 9.9 %. No *S. haematobium* was found in Chilubi, Ndola and Shangombo districts which leaves more than 95 % of the districts are endemic.

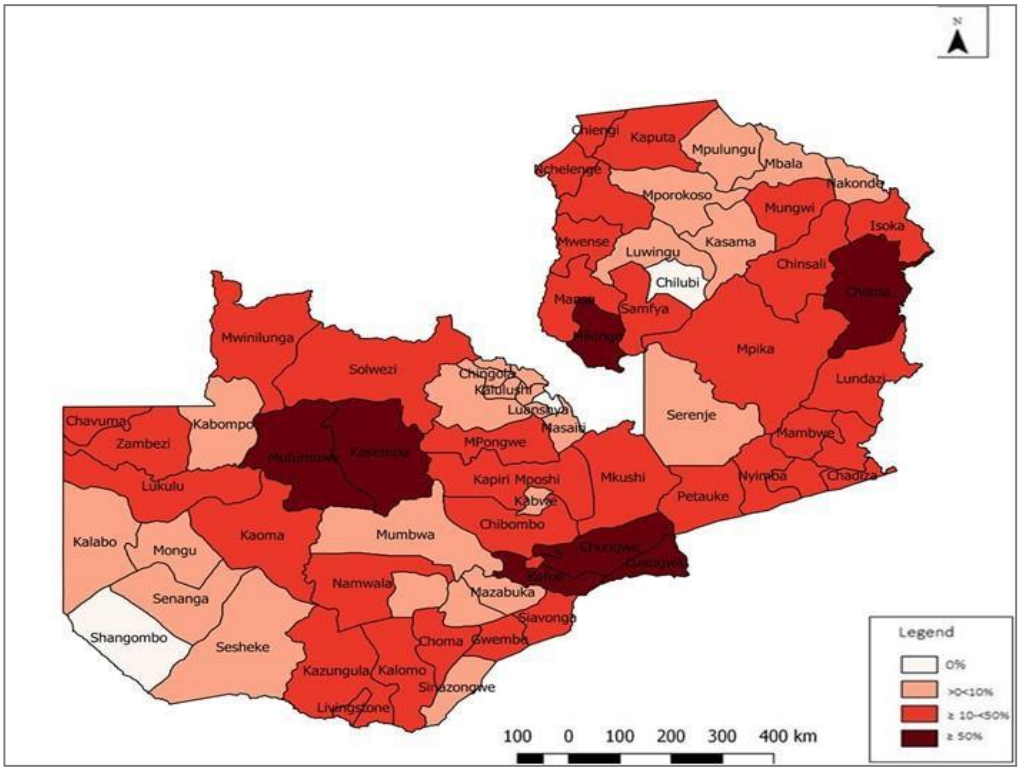


Figure 4-10 Map showing the district distribution of *S. haematobium* in Zambia

The distribution of *S. haematobium* at district level. Dark red districts have high prevalence, red moderate, pink low and light pink non-endemic

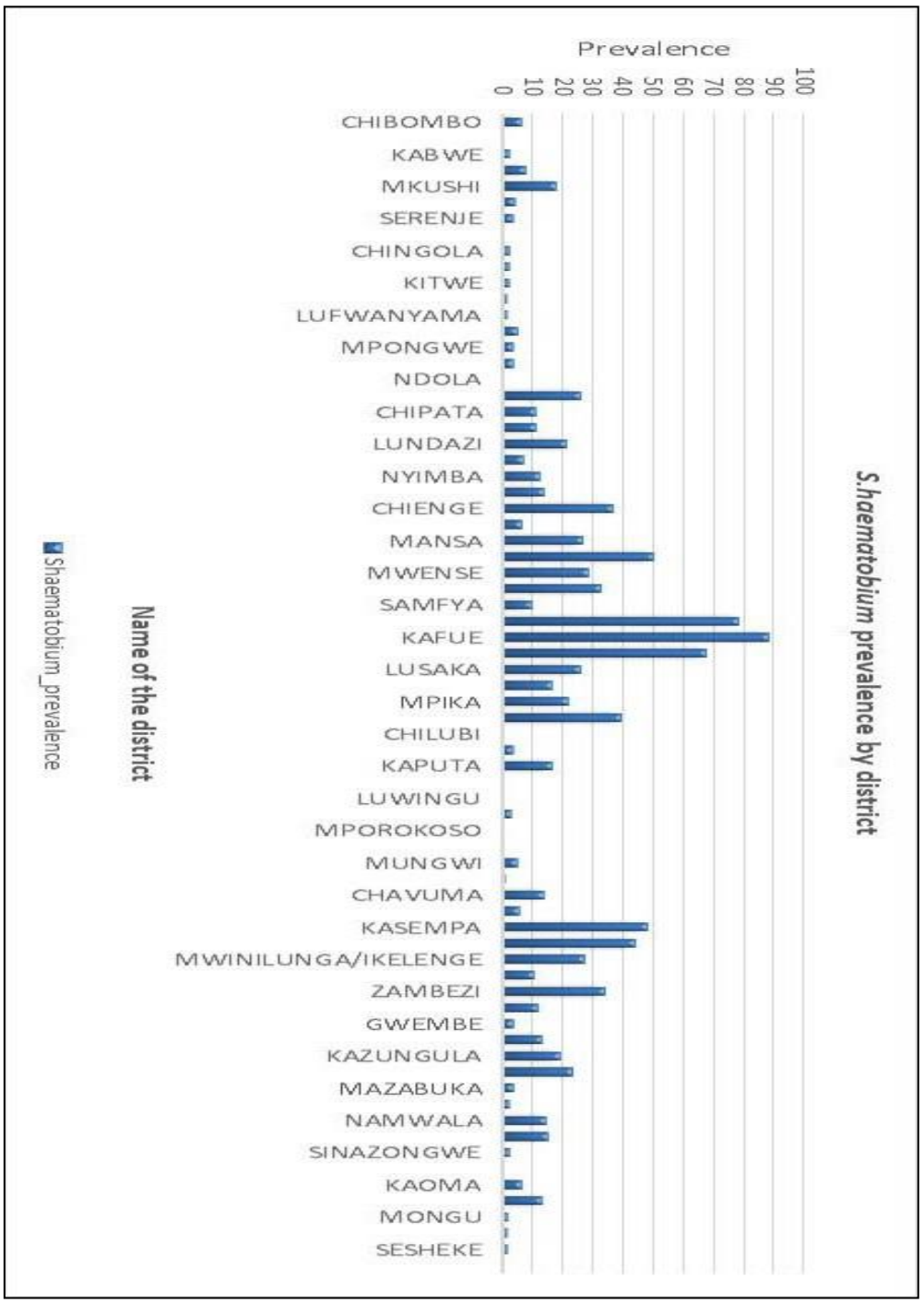


Figure 4-11 Distribution of the *S. haematobium* prevalence by district in the study population

S. mansoni

At district level the prevalence rates ranged from 0 to 24.2 % with the highest rates in Zambezi (24.2 %), Chavuma (24.1 %) and Kabompo (14.4 %) districts of Northwestern Province shown in Figures 4-12 and 4-13 and appendix 3 table 3. No district had prevalence rates above 50 % however, 7 districts (9.7 %) had

prevalence rates from 10 to 49.9 % and 42 districts (58.3 %) had prevalence rates from 0.1 to 9.9 %. No *S. Mansoni* was found in 23 districts which makes 68.0 % of the districts endemic.

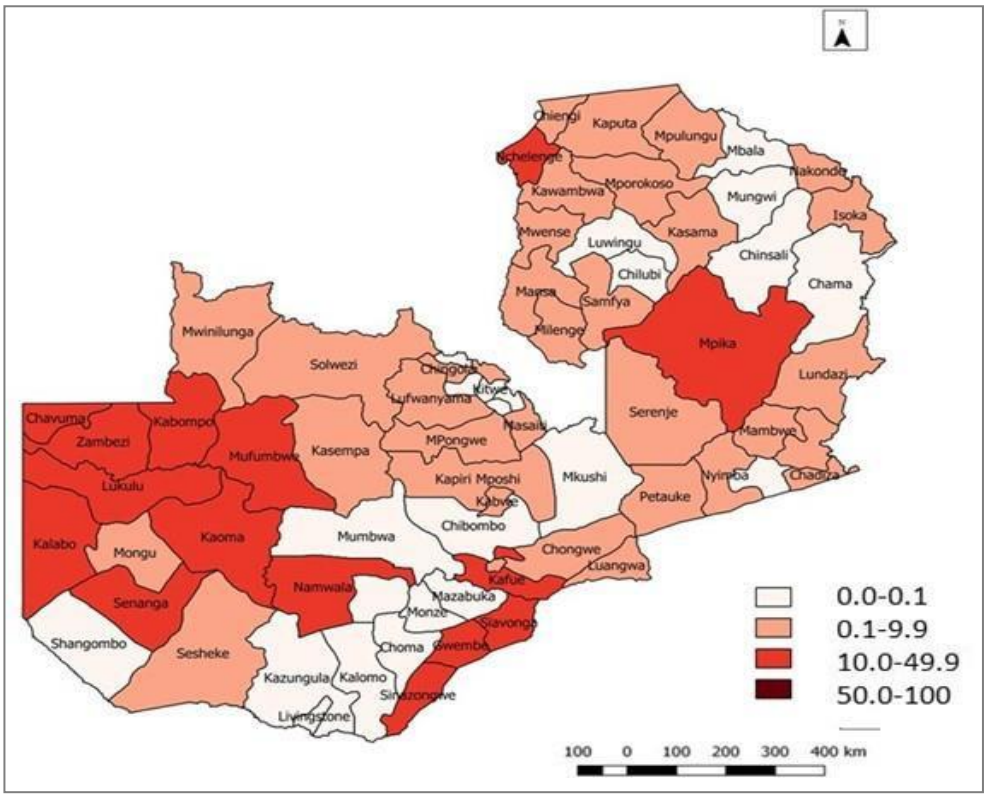


Figure 4-12 Map showing the district distribution of *S. mansoni* in Zambia

The districts with moderate prevalence is in the Western part of Zambia.

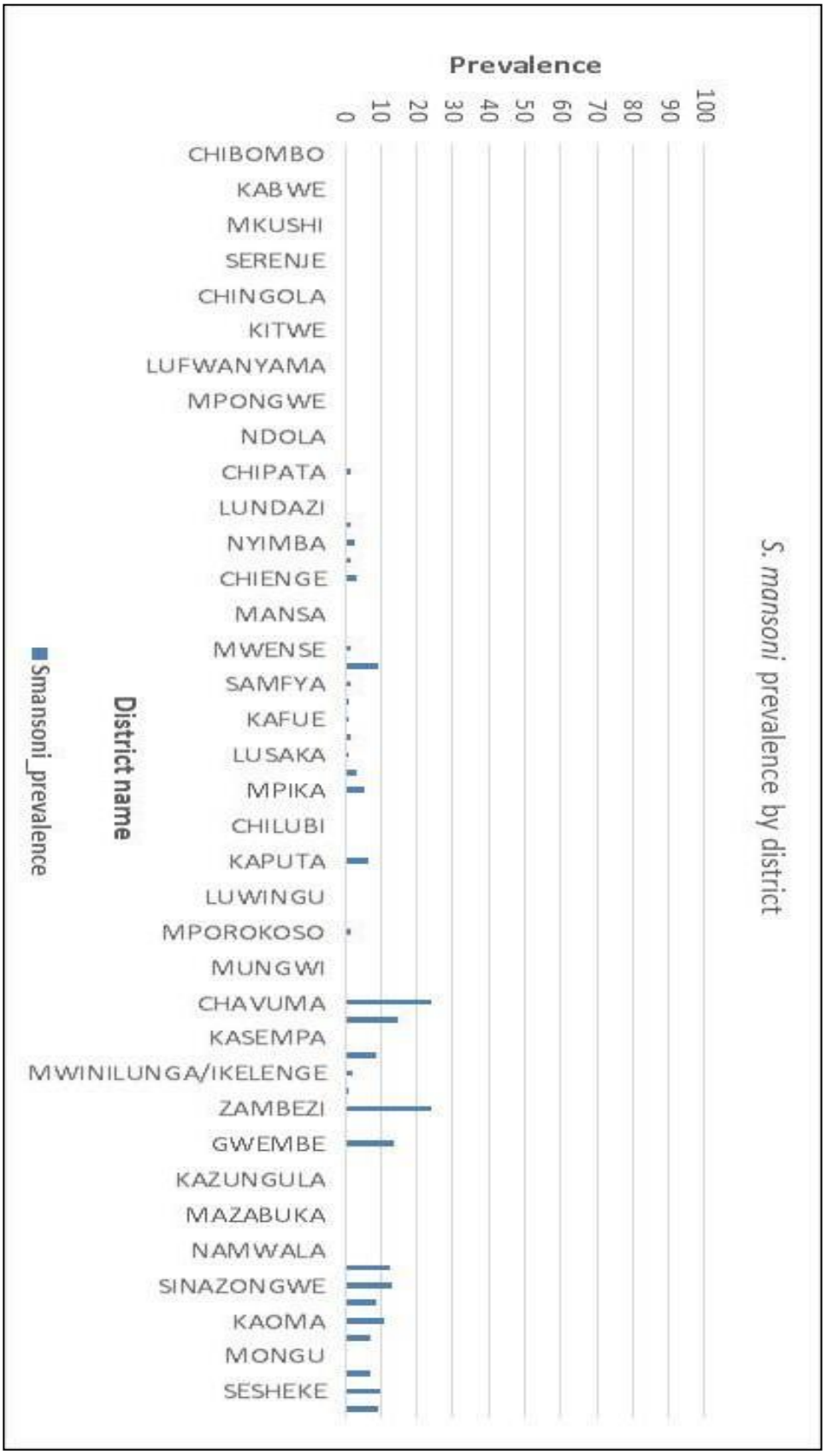


Figure 4-13 Distribution of *S. mansoni* prevalence rates by districts in the study population

Overall schistosomiasis

At district level the prevalence rates ranged from 0 to 87.7% with the highest rates in Kafue (87.7%), Chongwe (78.9%) and Luangwa (67.8%) Districts all of Lusaka Province as shown in Figure 4-14 and Figure 4-15. No schistosomiasis was found in Ndola and Chilubi districts. 11.1% (8) districts had high prevalence above 50%, 48.6 % (35 districts) had prevalence between 10 and 49.9% and 38.8 % (28 districts) prevalence below 10%.

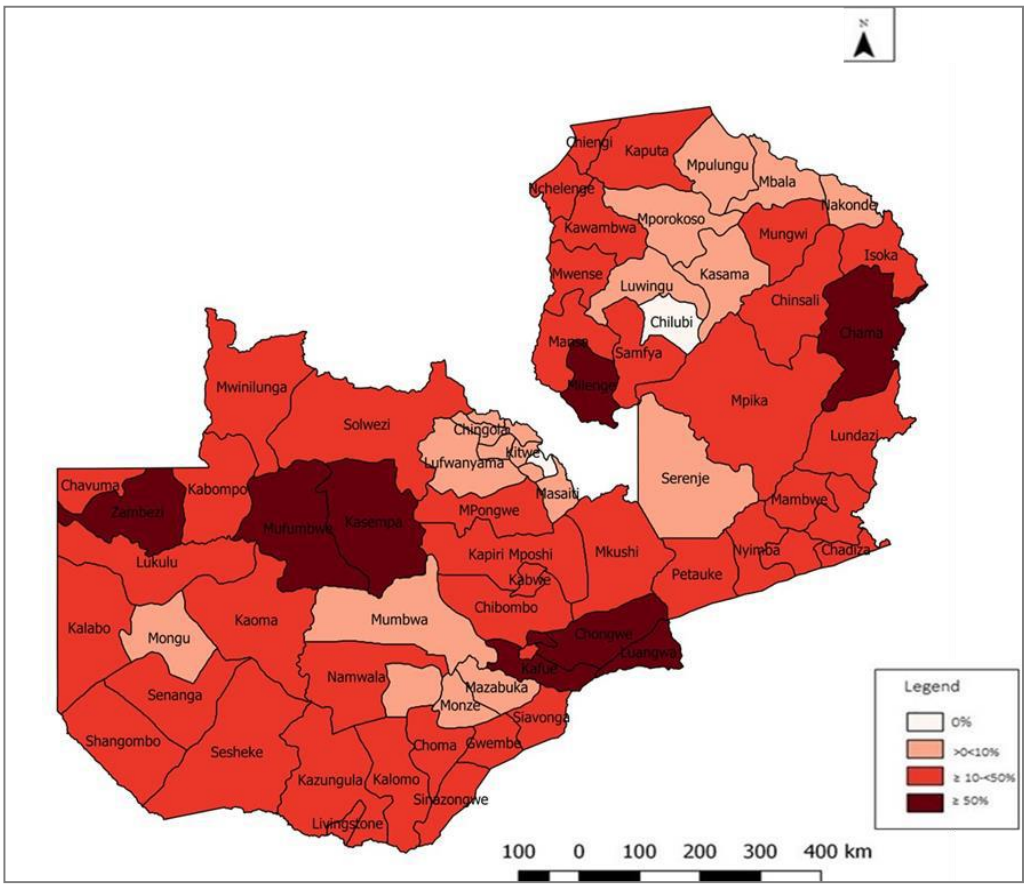


Figure 4-14 Map showing the district distribution of schistosomiasis in Zambia

The distribution of schistosomiasis at district level. Dark red districts have high prevalence, red moderate, pink low and light pink non-endemic

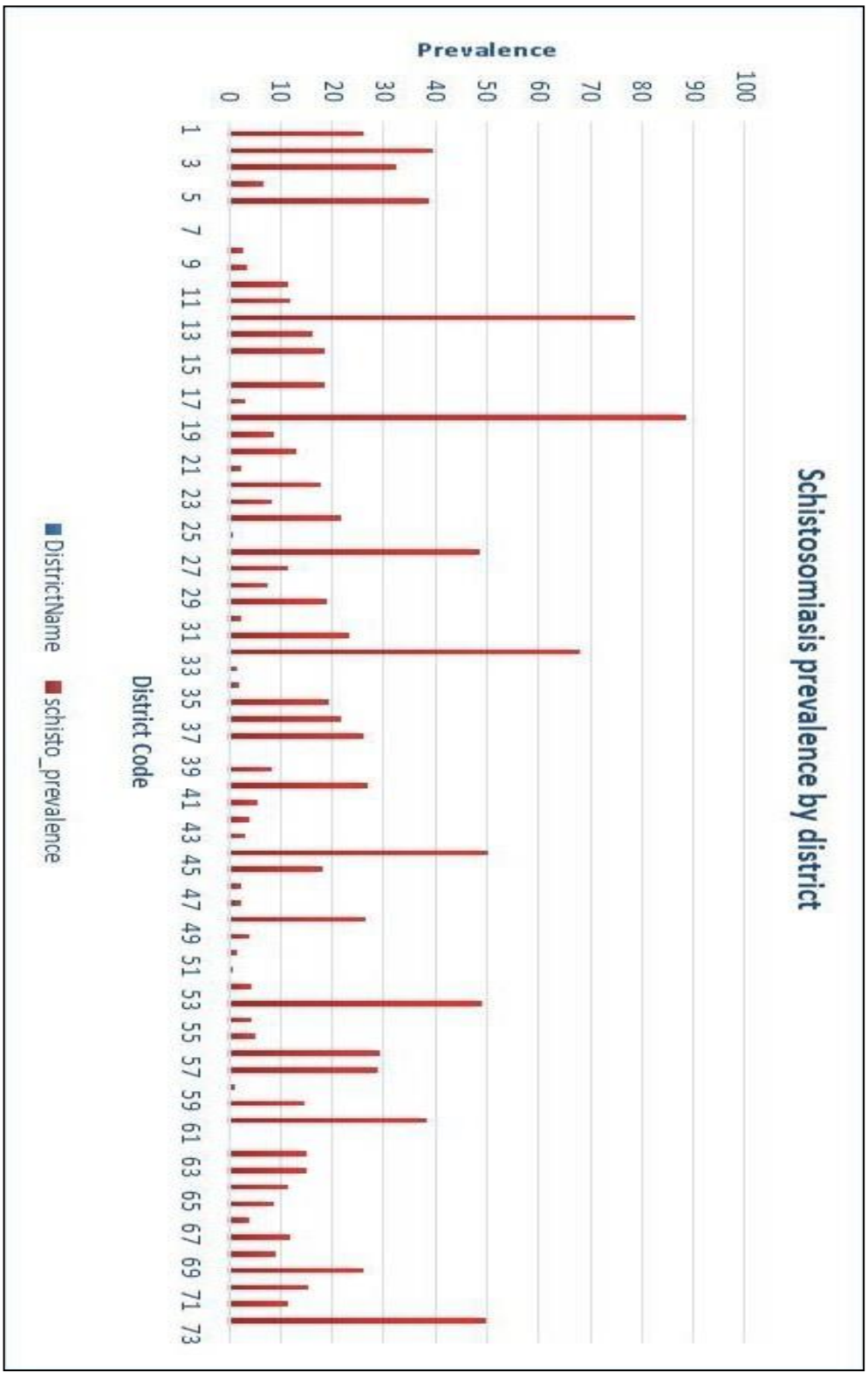


Figure 4-15 Graph showing overall schistosomiasis prevalence by district in Zambia in the study population

4.5.1.3 Distribution of schistosomiasis at school levels

S. haematobium

Overall, at school level, the prevalence rate ranged between 0 and 100 %. Out of a total of 1349 schools sampled, there was no detection of *S. haematobium* eggs in the urine of children at 570 (42.0 %) schools. Most of these schools were from Northern province (132 schools), Copperbelt Province (122 schools) and Central Province (72 schools). However, 100% infection was detected in children from 12 schools out of which 8 were from Kafue District (Chiparamba, Chikola, Chrambira, Chipapa, Shikoswe, Kamanga and Kaseba Primary Schools), 2 from Luangwa (Mwavwi and Mupushu Primry schools), 1 from Namwala (Lubanga Primary School) and another one from Chongwe (Nyangwenya Primary School). A total of 148 (11.0 %) schools had infection rate above 50%, while 375 (27.9 %) schools had infection rates between 10 and 49.9 % and the remaining 255 (18.2 %) schools had infection rates below 10%. These schools are shown in the point prevalence map in Figure 4-16. In order the show over dispersion and focalisation of *S. haematobium* a graph plotted for school prevalence across 1349 schools with a mean prevalence of 15.1 %, ranked in ascending order from 0 to 100 % was produced as shown in Figure 4-17.

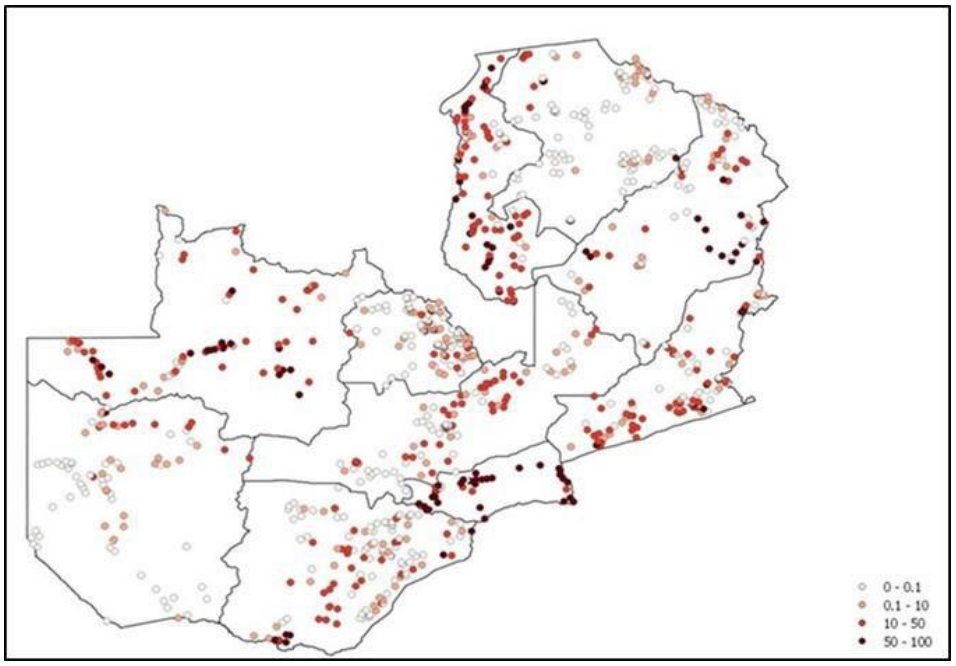


Figure 4-16 Point prevalence map for *S. haematobium* in Zambia

The map is showing the prevalence at the school level for S. haematobium. This map was produced using the data from the study.

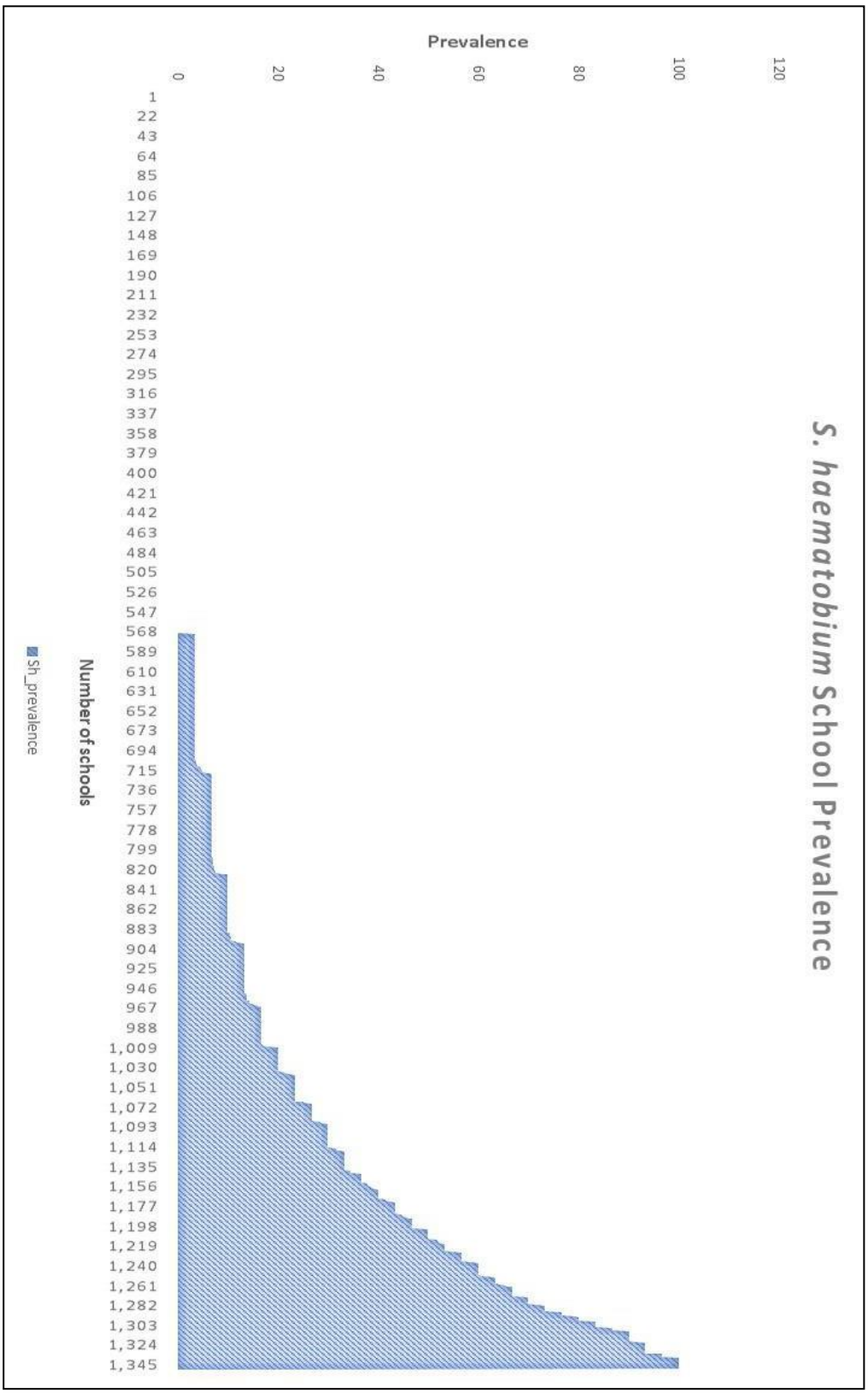


Figure 4-17 Graph showing schools ranked by prevalence for S haematobium.

The curve indicates that more than 70% of the schools were endemic for S. haematobium with the curve going all the way up to 100%

S. mansoni

Overall, at school level, the prevalence rate ranged between 0 and 80 %. Out of a total of 1349 schools sampled, there was no detection of *S. mansoni* eggs in the urine of children from 1045 ((77.4 %) schools. Most of these schools were from Copperbelt Province (172 schools), Northern province (159 schools), Southern Province (144) and Central Province (135 schools). However, 80% infection was detected in children at 1 school from Sesheke District (Imusho Primary School). Other schools that reported high prevalence above 50 % were Kariba South Primary school in Sinazongwe (76.7%), Chivula Basic School in Sesheke (66.7 one school in Chavuma (65.5 %), one school in Zambezi (65.0 %), Siangoma in Sinazongwe and Fumbo in Gwembe with 50% prevalence each making a total of 7 (0.5 %) of sampled schools with high prevalence rate. Only 9.4% had moderate risk and 12.6% low risk as shown in Figure 4-18. The plot of school prevalence of *S. mansoni* across 1349 schools with a mean prevalence of 2.9%, ranked in ascending order showed the well-known pattern of over dispersion or focalisation in Figure 4-19.

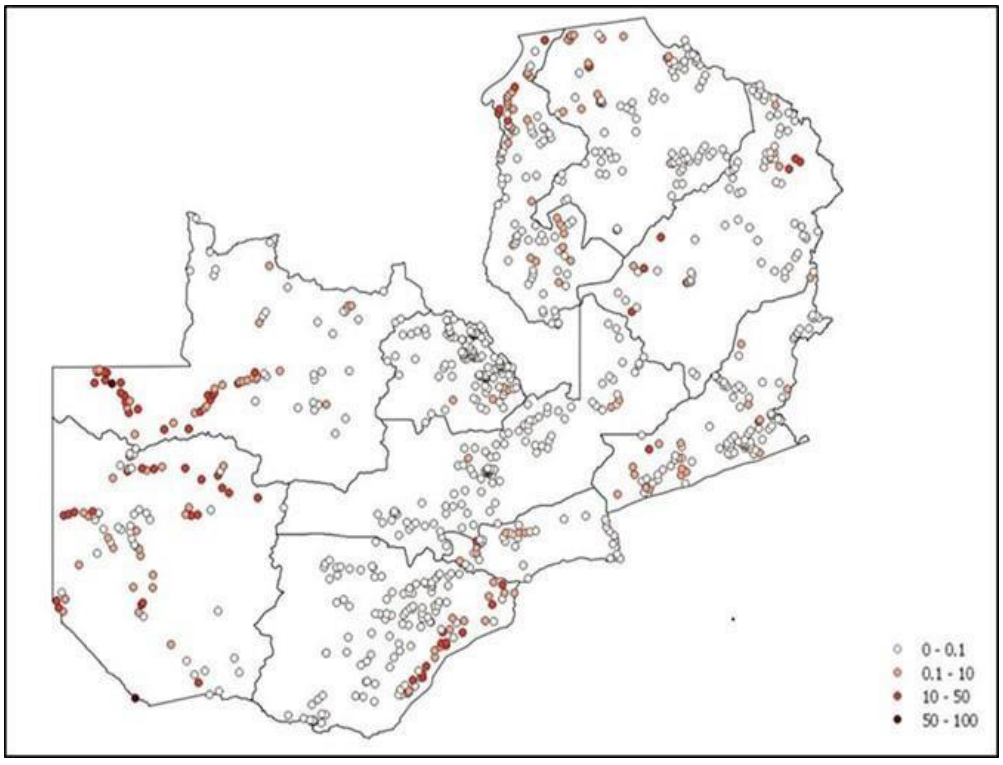


Figure 4-18 Point prevalence map for *S. mansoni* in Zambia

The prevalence recorded at each school for *S. mansoni* in Zambia. The concentration of highly endemic schools in the Western part.

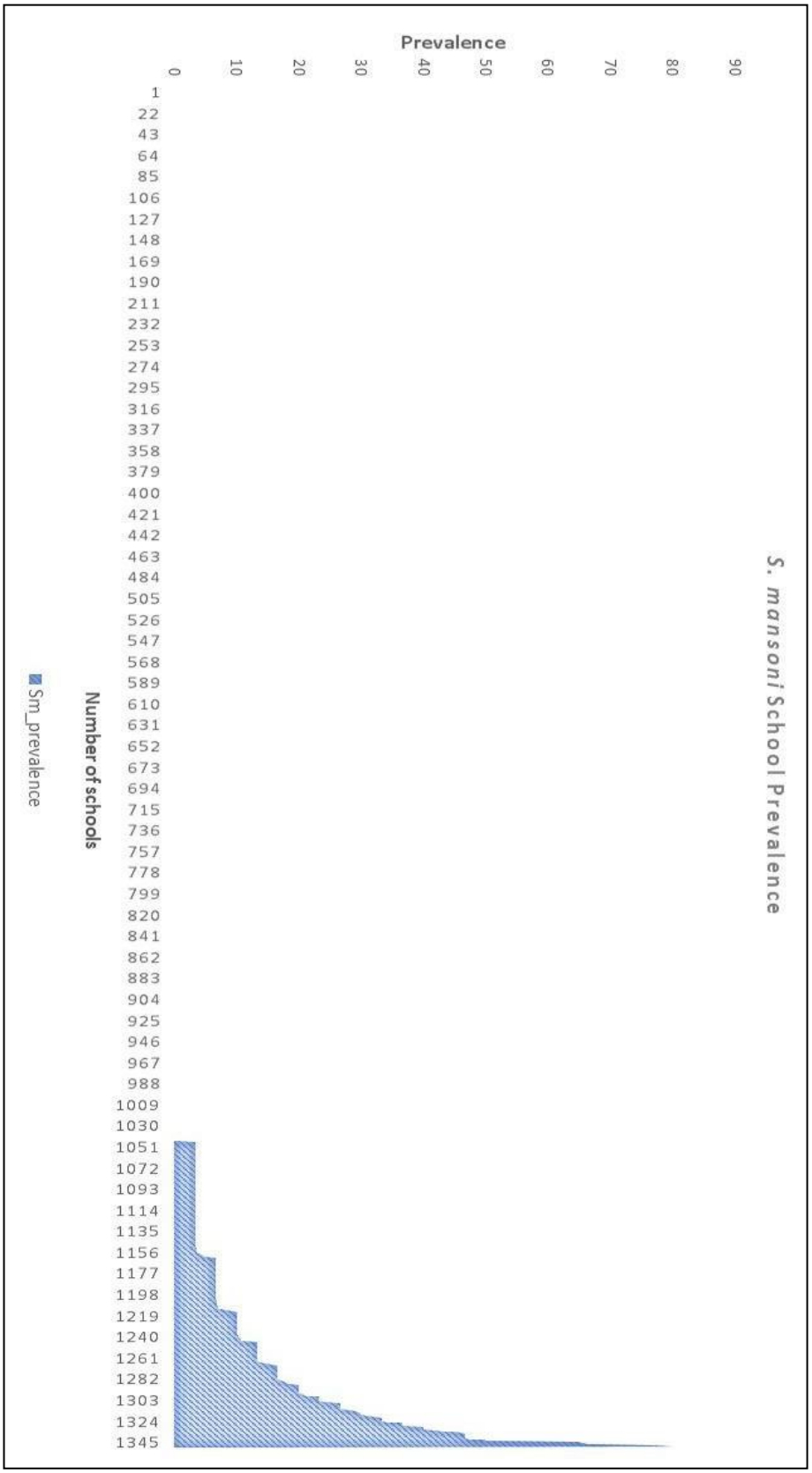


Figure 4-19 Graph showing schools ranked by prevalence for *S. mansoni* in Zambia

The curve shows that quarter of the schools were endemic with low prevalence rate very few schools had prevalence above 50%

Overall schistosomiasis

Overall schistosomiasis points prevalence or school level prevalence ranged from 0 – 100%, as shown in Figure 4-20 with the highest rate (100% positivity at 8 schools in Kafue, 2 schools in Luangwa and 1 school each in Chongwe and Namwala. In addition, 12.6% (170 schools) of the schools had prevalence over 50% classified as high risk, 33.3% (449 schools) had moderate risk and 18.9% (245 schools) low risk. While 36% (485 schools) where found to be non-endemic. The median schistosomiasis prevalence was 6.67% with a mode of 0.0% and mean prevalence of 17.2%. The plot of school prevalence of schistosomiasis across 1349 schools with a mean prevalence of 17.4% ranked in ascending order highlights the over dispersion or focalisation for overall schistosomiasis in Figure 4-21.

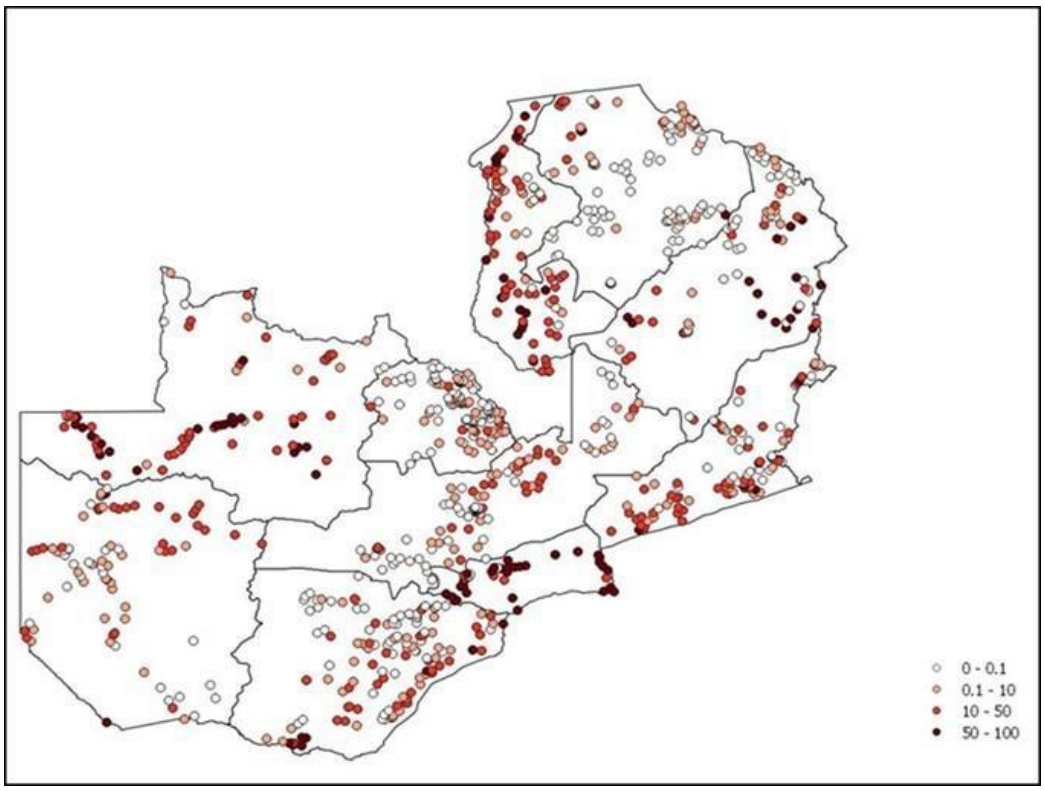


Figure 4-20 Point prevalence map for schistosomiasis in Zambia

The map of the school level prevalence rates showing across the country for over 1000 schools. The maps were produced using the study data.

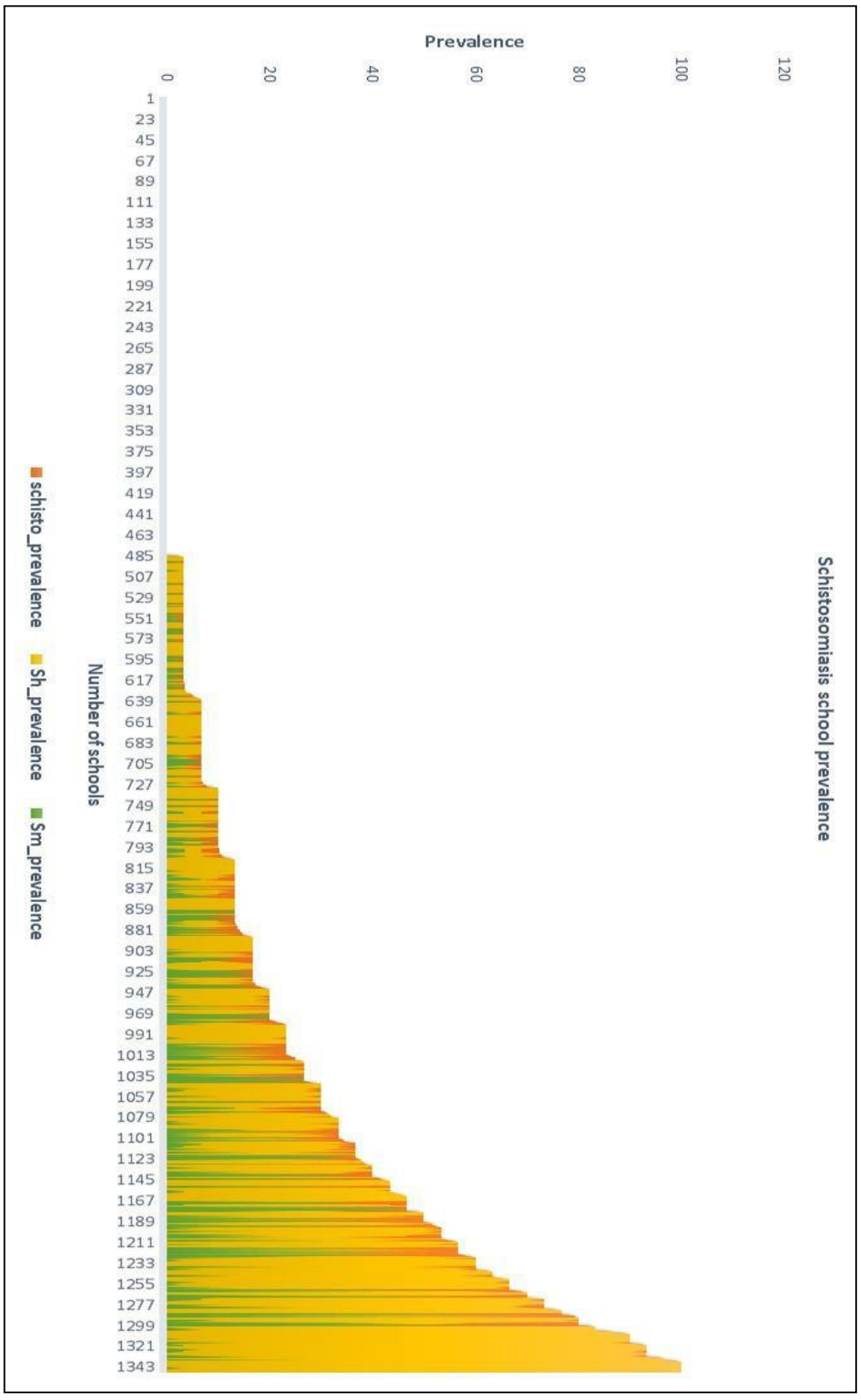


Figure 4-21 Graph showing schools ranked by prevalence for schistosomiasis in Zambia

The curve shows ranking of the individual Schistosoma species and co-infection reported at school level. Over 70% of the schools were endemic for any Schistosoma or combined.

4.5.1.4 Distribution of Soil transmitted helminths at National and Provincial levels

Hookworm

The national prevalence of hookworm was 18.0% (95% Confidence Interval 15.6-20.5%) and the provincial prevalence rates ranged from 3.3-40.7% in Table 4-3 with significantly higher rates recorded in Northwestern (40.7%, Western (38.8%), Northern (23.4%) and Muchinga (21.3%) Provinces had significantly high prevalence with the upper 95% confidence interval above the mean prevalence 20.5%. A significantly low prevalence of 3.3% was recorded in Southern Province with other lower rates recorded in Eastern (9.4%) and Central (9.5%) Provinces. These findings are displayed in Figures 4-22 and 4-23.

Table 4-3 Summary Table of soil transmitted helminthiasis species and co-infection provincial prevalence rates in the study population

Category	N	Hookworm % *(CI_{95})*	Ascaris% *(CI_{95})*	Trichuria % *(CI_{95})*	STH *(CI_{95})*	Co-infection
Central	4200	9.5(7.3, 11.8)	1.2(0.7-1.6)	0	10.6(8.4-12.8)	0.2
Copperbelt	5295	10.6(8.3,12.9	14.8(11.7-18)	0	25.8(22.6-29)	0.4
Eastern	3870	9.47.5,11.9)	3.3(2.3-4.3)	0	12.4(10.3-14.5)	0.3
Luapula	2981	12.1(10.3,14)	5.7(3.9-7.5)	0	17.9(15.0-20.8)	0.5
Lusaka	2378	11.1(9.3,12.9)	7.7(6.0-9.5)	0	18.2(15.3-21.2)	0.6
Muchinga	2546	21.3(17.3,25)	1.6(0.8-2.4)	0	23(19.0-26.9)	0.3
Northern	4917	23.4(20.,26.5)	3.5(2.4-4.5)	0	26.5(23.4-29.5)	0.8
Northwestern	3568	40.7(38,43.7)	1.2(0.7-1.7)	0	41.9(38.9-44.8)	0.4
Southern	5484	3.3(2.4,4.2)	1(0.6-1.4)	0	4.3(3.3-5.3)	0
Western	3313	38.8(35,42.4)	0.3(0.1-0.5)	0	39.1(35.5-42.7)	0.1
National	38552	18(15.6-20.5)	4(2.9-5.1)	0	22(19.2-24.8)	0.3

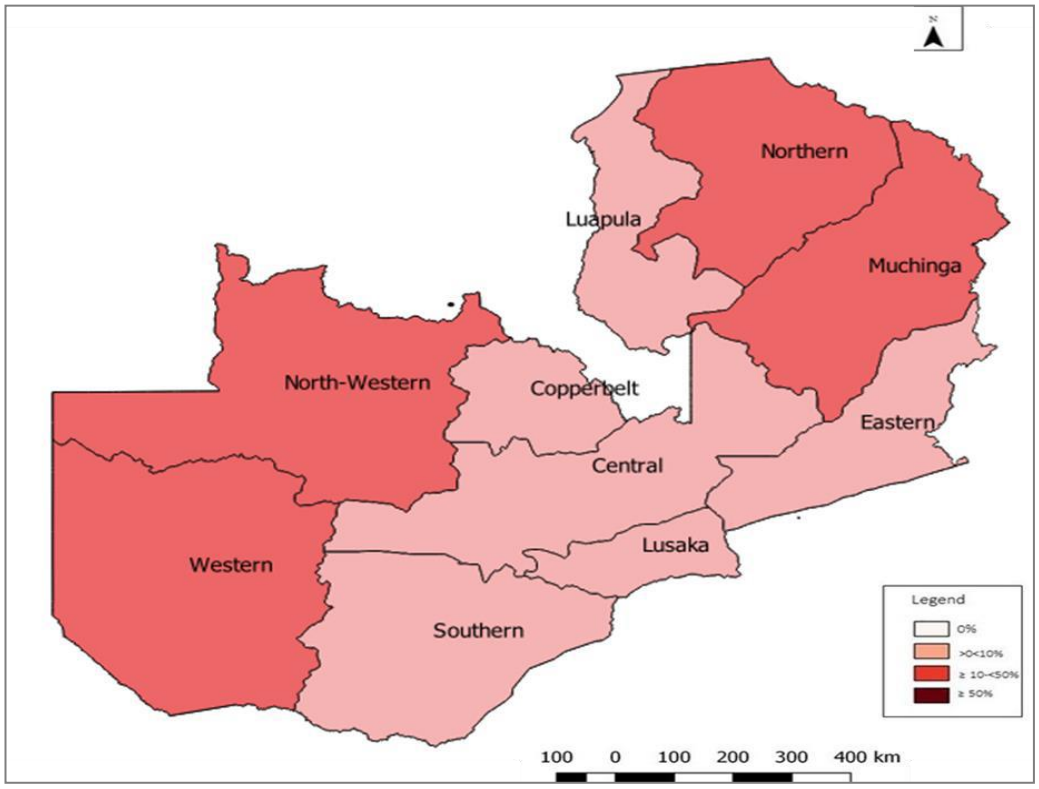


Figure 4-22 Map showing hookworm distribution at provincial level in the study population

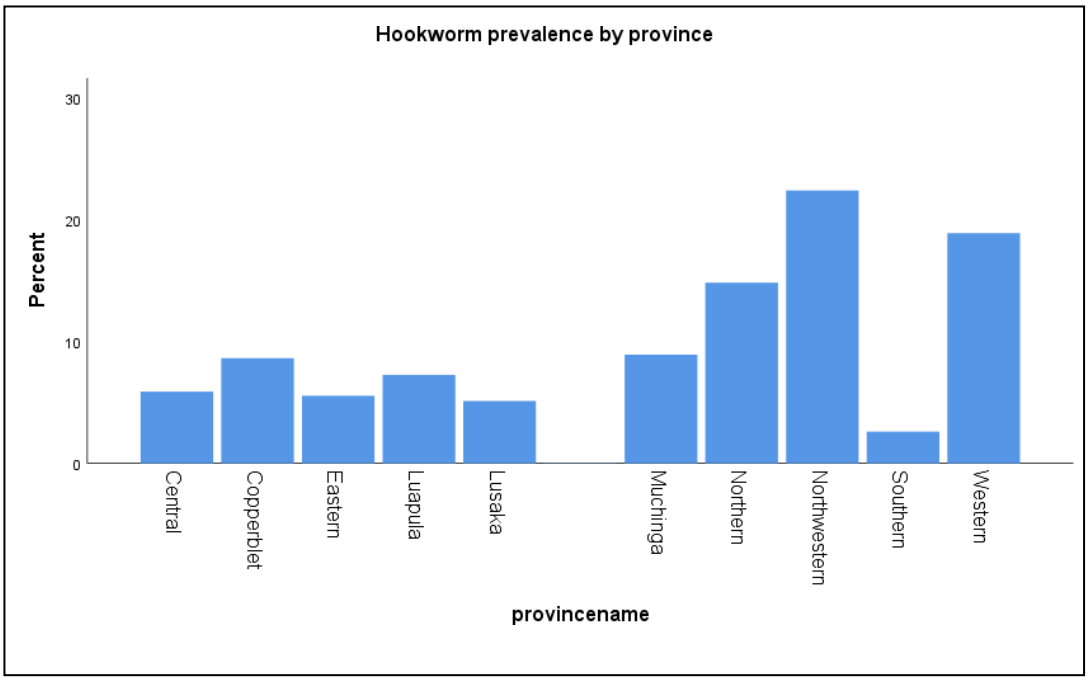


Figure 4-23 Graph showing the provincial distribution of hookworm in Zambia in the study population

A. lumbricoides infections

The national prevalence of *A. lumbricoides* was 4.1% (95% Confidence Interval 2.9-5.1%) and the provincial prevalence rates ranged from 0.3-14.8% (Table 4-3). Copperbelt had significantly high prevalence with confidence interval above the mean prevalence from 11.7-18.0%. The lowest prevalence was recorded in Western (0.3%), Southern (1.0%), Northwestern and Central at 1.2% each (Table 4-3). Copperbelt (14.8%) was found to have significantly higher rates than all the provinces as shown in Figure 4-24 and 4-25, followed by Lusaka (7.7%), Luapula (5.7%) and Northern (3.5%) provinces.

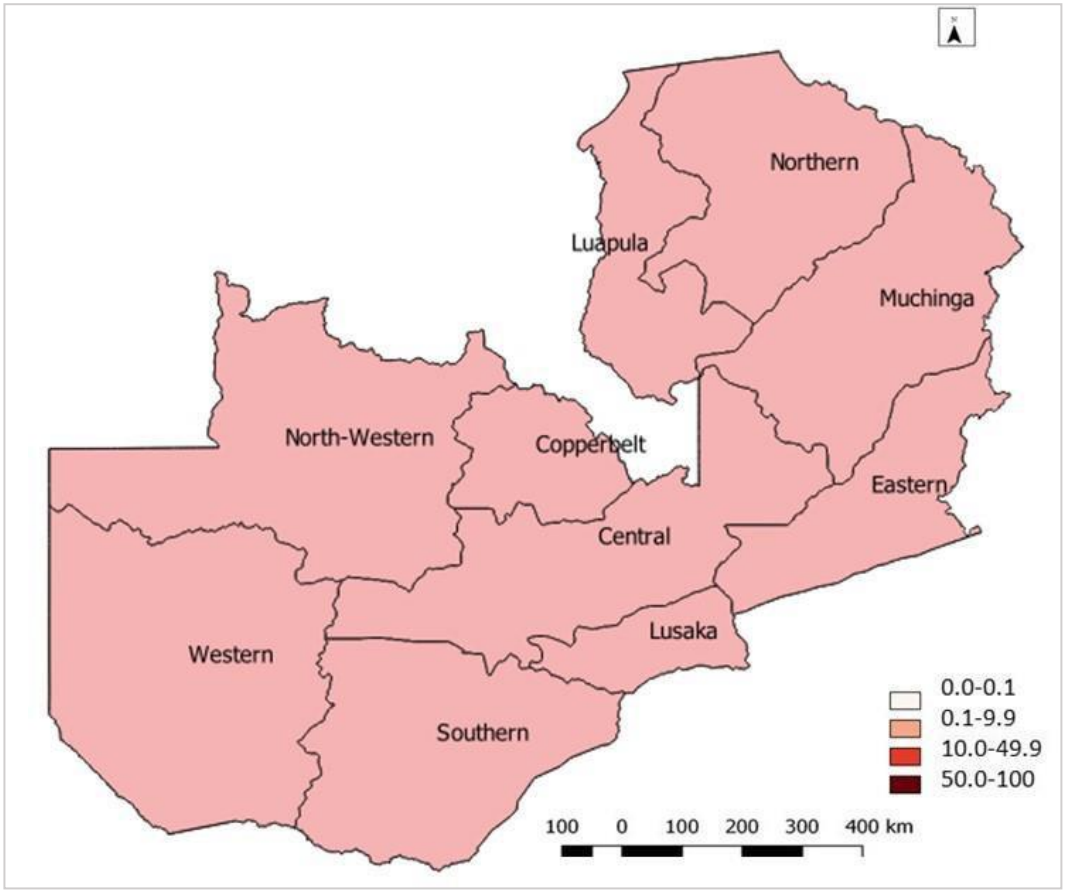


Figure 4-24 *A. lumbricoides* provincial prevalence map for Zambia in the study population

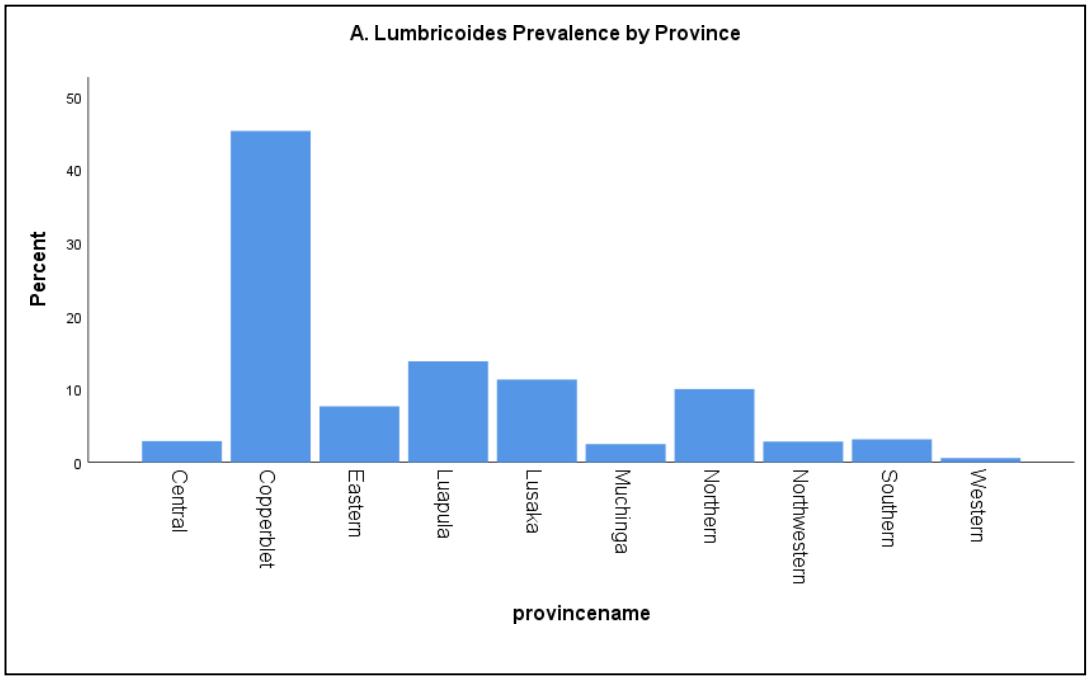


Figure 4-25 Graph showing the provincial prevalence for *A. lumbricoides* in the 10 provinces of Zambia

Trichuria trichiura

The overall prevalence of *T. trichiura* at provincial level was 0.0% as indicated in Table 4-3 and Figure 4-34.

4.5.1.5 Distribution of soil transmitted helminths at District

Hookworm

The district prevalence rates for hookworm ranged from 0.0-52.6% Figure 4-26 and Figure 4-27. 32 districts recorded prevalence rates above the mean of 14.98%. However, Mwinilunga (52.6%), Lukulu (49.5%), Chilubi (49.3%), Sesheke (48.3%), Kasempa (47.7%) and Chinsali (40.6%) had significantly high prevalence with confidence interval above the mean prevalence. All the districts were endemic with varying prevalence except for Itezhi-tezhi that had a prevalence rate of 0%. Most of the concentration of moderate to high prevalence was to the north-western part of the country as shown in Figure 4-26.

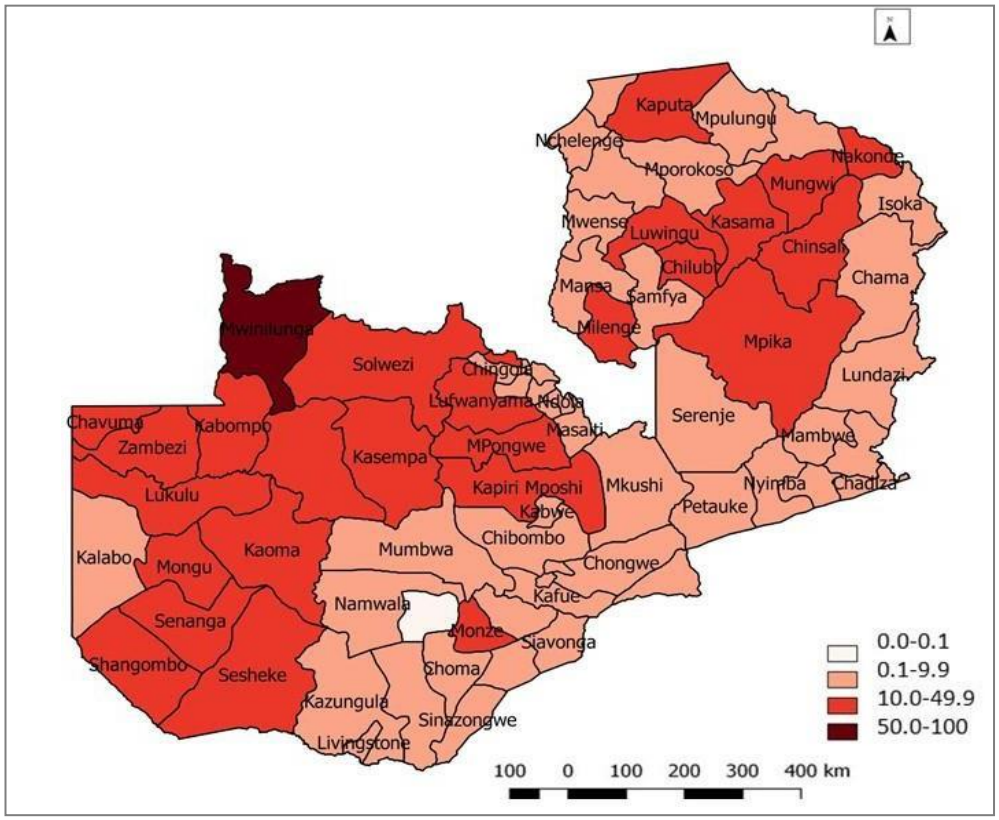


Figure 4-26 Map showing the district level distribution of hookworm in the study population

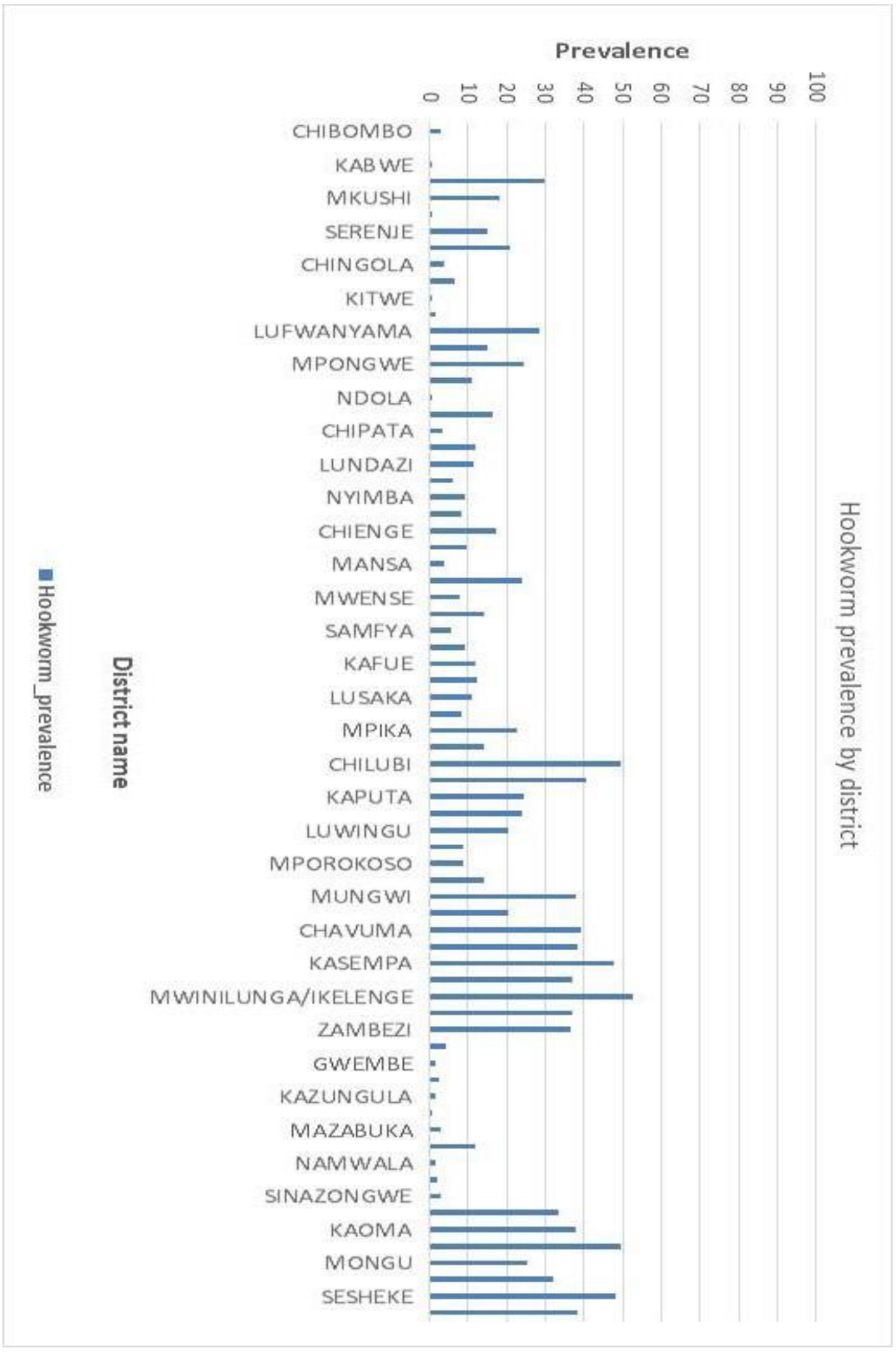


Figure 4-27 Bar graphs showing the prevalence of hookworm at district level.

A. lumbricoides

At district level, the prevalence rates ranged from 0 to 40.2% with the highest rates in Mufulira and Kitwe districts, both from Coppperbelt Province as shown in Figure 4-28 and 4-29. Mufulira (40.2%), Kitwe (34.8%), Milengi (27.5%), Luanshya (18.3%), Kasama (15.3%), Kalulushi (14.5%), Petauke (13.3%), Chililabombwe (10.5%), Luangwa (10.3%), Ndola (9.2%), Lusaka (9.0%), Chingola (7.9%) and Nyimba (7.3%) had significantly high prevalence with confidence interval above the mean prevalence 4.0%. Most of the districts recorded low prevalence below the mean. Nchelenge, Kaputa, Mporokoso, Gwembe, Monze, Kaoma, Sesheke and Shangombo did not detect any *Ascaris* eggs in the collected stool samples.

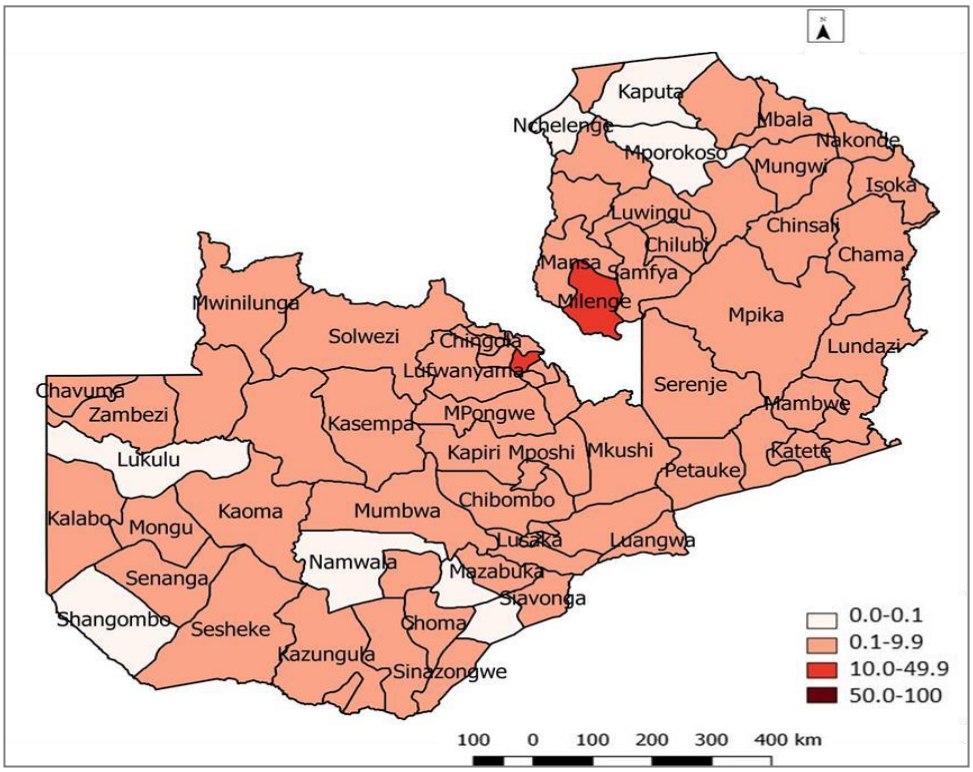


Figure 4-28 District level prevalence map for *A. lumbricoides* in the study population

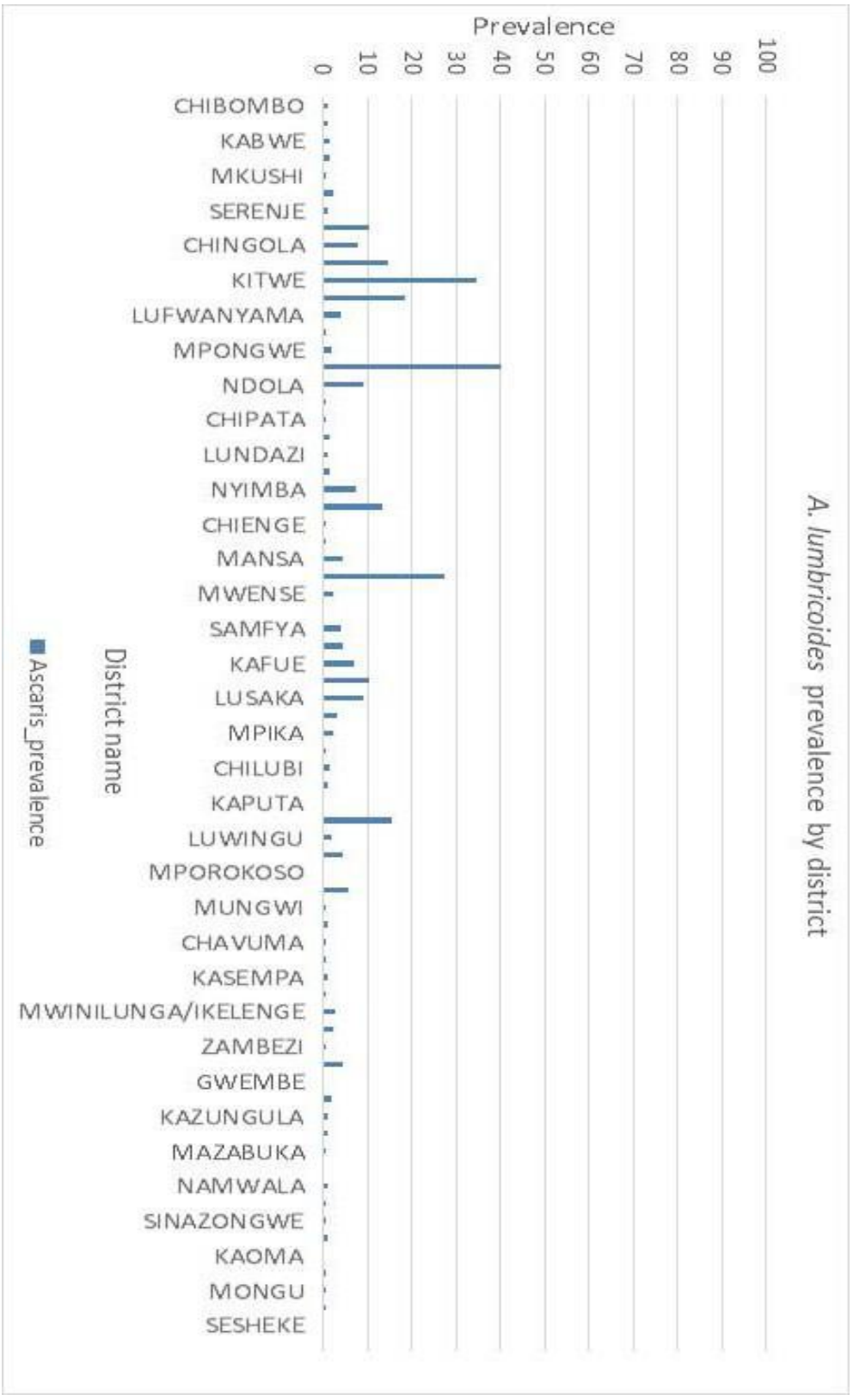


Figure 4-29 Bar charts showing district level *A. lumbricoides* prevalence of Zambia in the study population

Trichuria trichiura

Only 30 districts had a prevalence above 0.1% with 40 districts recording 0.0 % prevalence rates in Figure 4-34. The mean prevalence for *T. trichiura* was 0.6% with only 5 districts having confidence intervals above the mean. Lufwanyama (3.16%), chilalabombwe (2.39%), Samfya (2.17%), Solwezi (1.51%) and Luwingu (1.38%) had the highest rates.

4.5.1.6 Distribution of soil transmitted helminthiasis at school levels

Hookworm

Hookworm point prevalence ranged from 0-90% in Figure 4-30 with a mean prevalence of 17.3% (95% Confidence Interval 15.6-20.5%). Very high ratesbetween 50-90% were reported at 108 schools. High rates were found in 9 schools in Mwinilunga, 7 schools in Chilubi, 6 schools each in Kasempa and Sesheke, 5 in Lukulu, 4 each in Chinsali and Kasama and 3 schools each in Mpika, Zambezi and kabompo. Of the 1349 schools sampled, 71.8% (n=969) recorded presence of hookworm. In addition, 8.0% schools had prevalence above 50% and classified as high risk, 28.3% low risk requiring MDA, and 35.5% low risk not requiring MDA. 28.2% schools were found to be non-endemic for hookworm. The plot of school prevalence of hookworm across 1349 schools with a mean prevalence of 17.3%, ranked in ascending order showed a well-known pattern of over dispersion or focalisation (Figure 4-31).

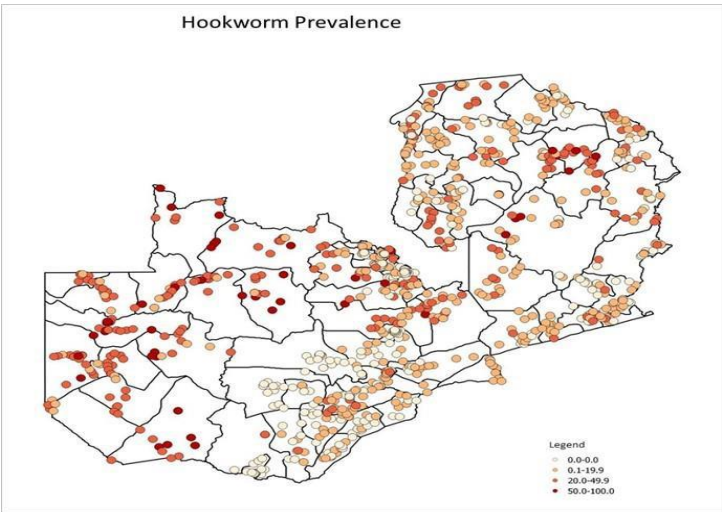


Figure 4-30 Map showing the point prevalence for hookworm in Zambia.

The points are the locations of the schools where the study was conducted, and the colour coding match the prevalence rates from low to high.

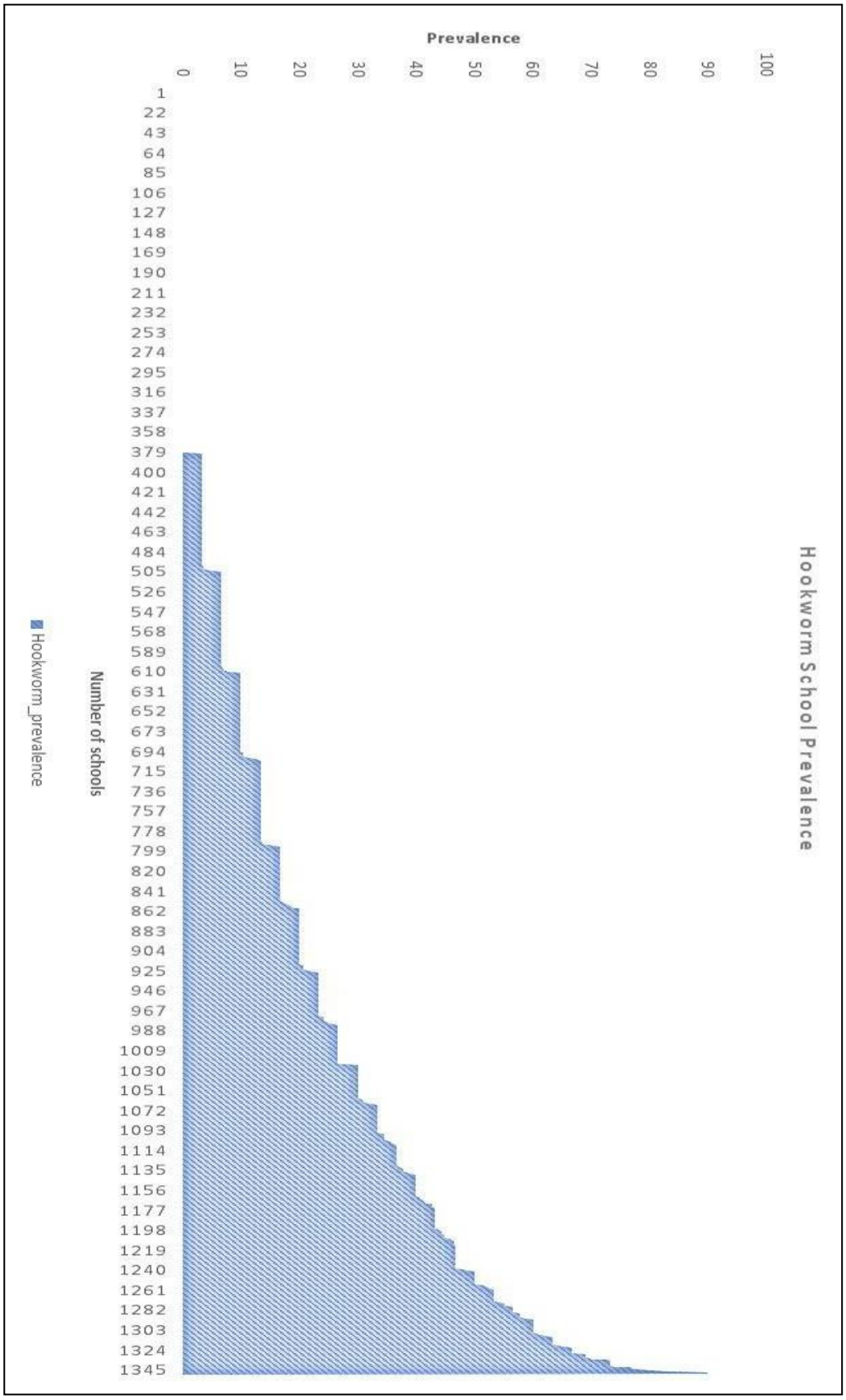


Figure 4-31 Graph showing schools ranked by prevalence for hookworm in Zambia

The curve shows ranking of hookworm reported at school level from low to high. Over 70% of the schools were endemic for any Schistosoma or combined.

A. lumbricoides

A. lumbricoides school point prevalence ranged from 0-80% (Figure 4-32) with a mean prevalence of 4.2% (95% Confidence Interval 2.9-5.1%) . The highest rates were found at 21 schools. High rates were found at 9 schools in Mufulira, 5 schools in Kitwe, 3 in Luanshya, 1 school each in Ndola, Milengi and Kalulushi. Of the 1349 schools sampled, only 33.8% (n=456) recorded presence of *A. lumbricoides*. In addition, 4.6% of endemic schools had prevalence above 50% and classified as high risk, 14.5% low risk requiring MDA, and 27.4% low risk not requiring MDA. 66.2% schools were found to be non-endemic for *A. lumbricoides*. The plot of school prevalence of *A. lumbricoides* across 1349 schools with a mean prevalence of 4.2%, ranked in ascending order according to the well-known pattern of over dispersion or focalisation in Fgure 4-33.

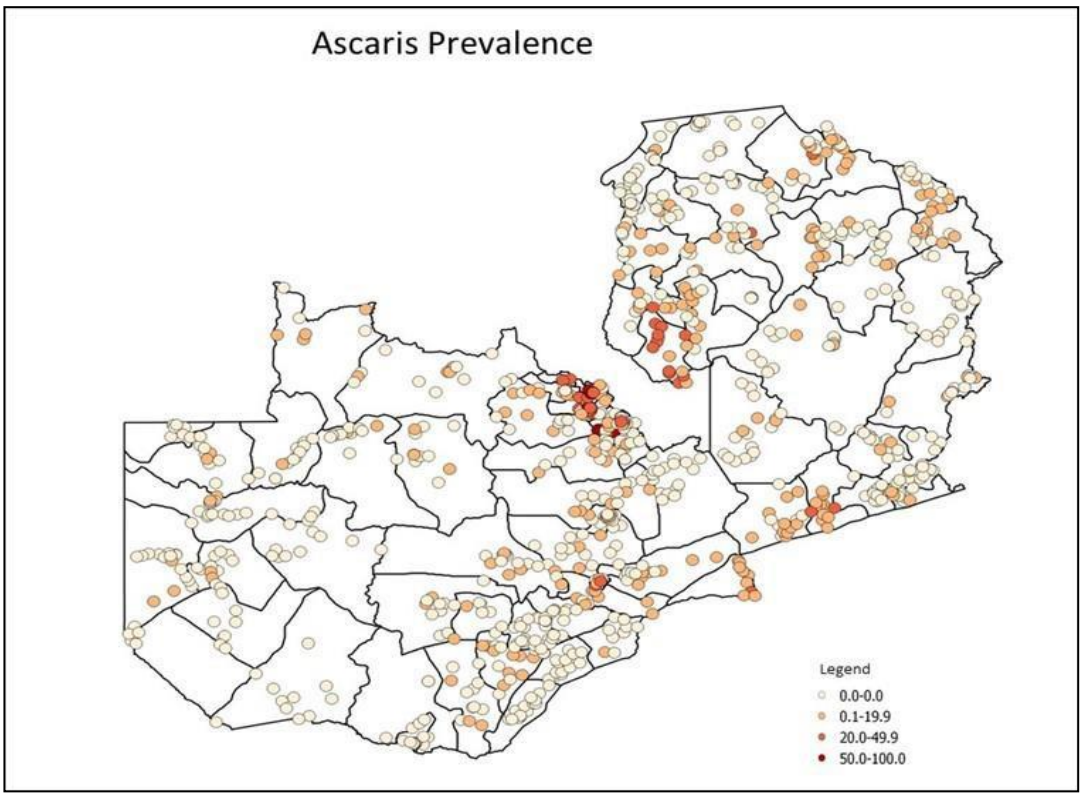


Figure 4-32 Point prevalence map for *A. lumbricoides* in Zambia

The points are the school locations where the study was conducted in the prevalence calculated in the study population.

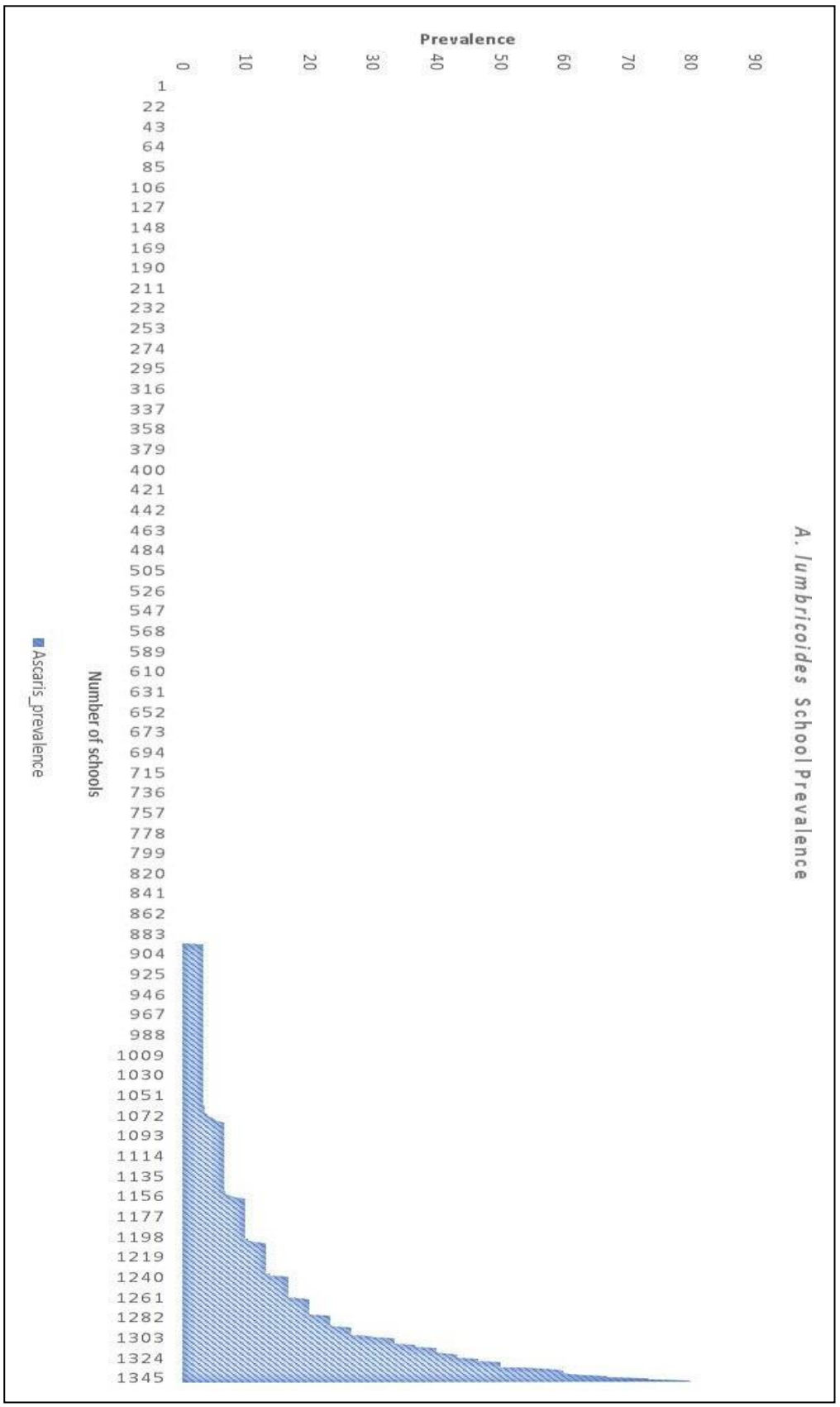


Figure 4-33 Graph showing schools ranked by prevalence for *A. lumbricoides* in Zambia of the study

The curve shows ranking of school infection from low to high of *A. lumbricoides* reported at school level using the study data. Less 50% of schools reported the infection

Trichuria trichiura

T. trichiura point prevalence ranged from 0-0.17% (Figure 4-34 C) with a mean prevalence of 0.6%. There were no high prevalence rates for *T. trichiura*. Co-endemicity with *A. lumbricoides* was just at 1 school and with hookworm at 4 schools. The plot of schools ranked in ascending order is shown in Figure 4-35.

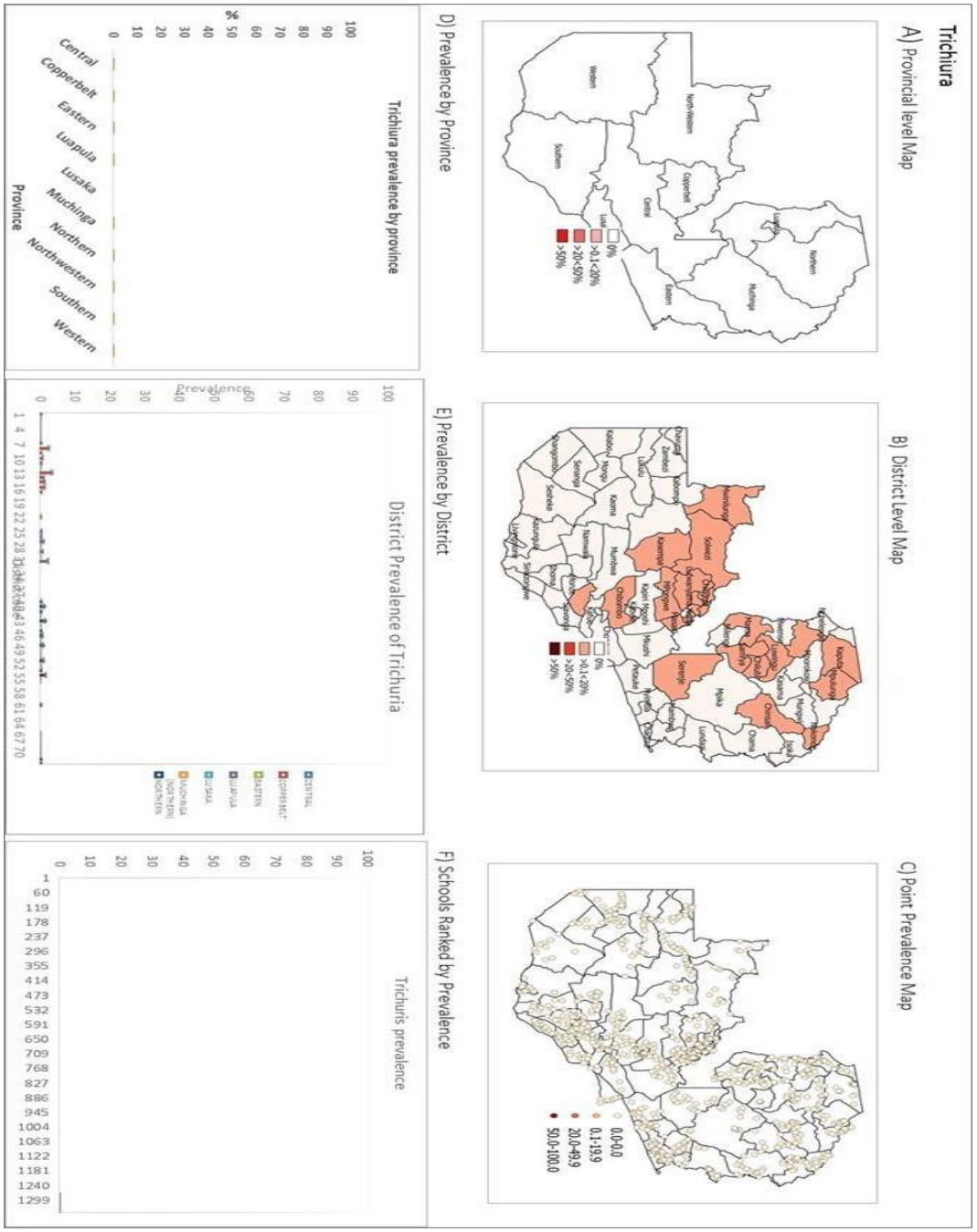


Figure 4-34 Maps and graphs showing the distribution of *T. trichuria* at provincial, district and school levels.

A Provincial level with 0 prevalence, B. District level with only a third of the district's lowly endemic, C. Most schools and non-endemic, these are reflected in the graphs in D-F.

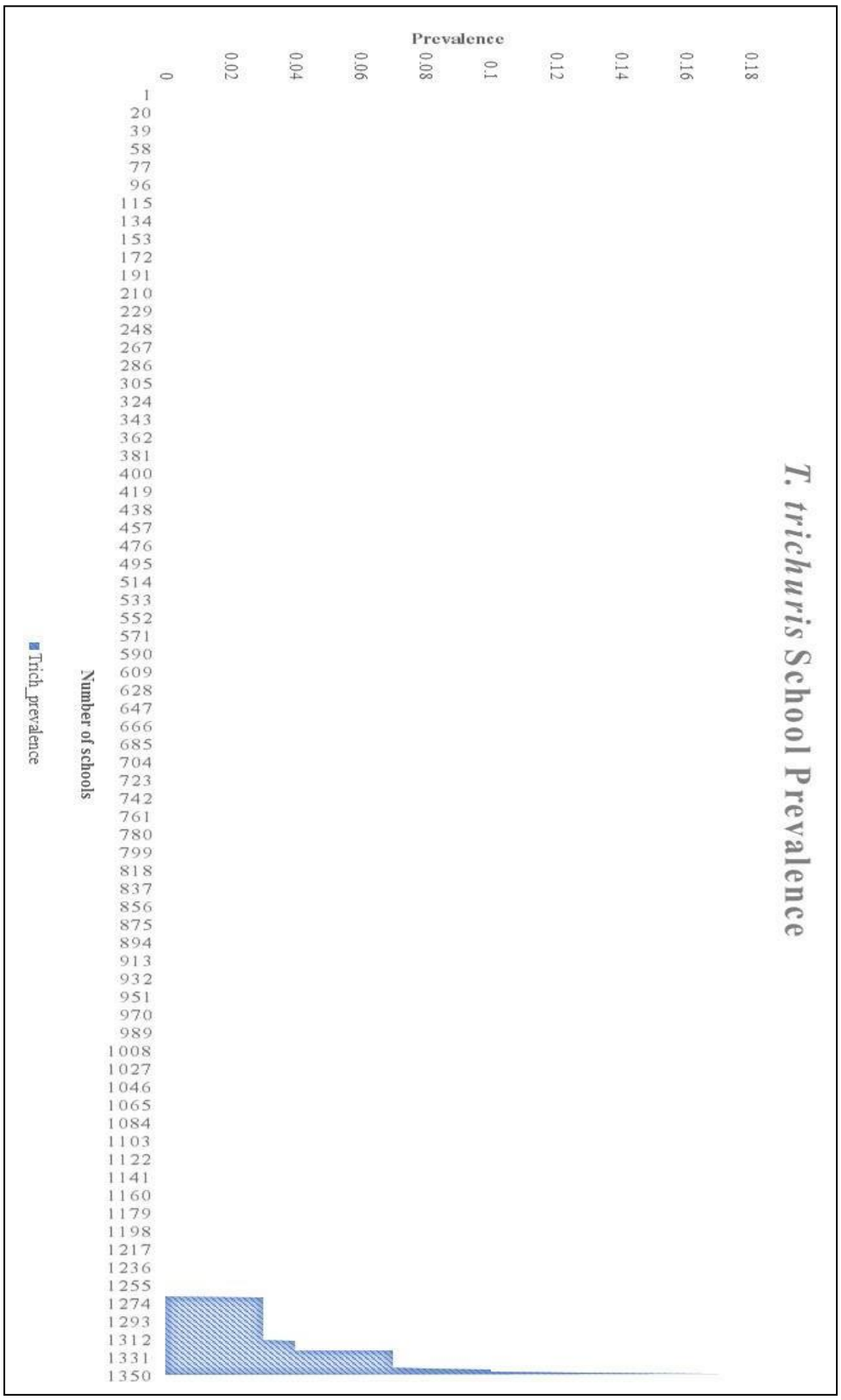


Figure 4-35 Graph showing schools ranked by prevalence for *T. trichuria* in Zambia of the study population

The curve is very low with all the schools plotted below a prevalence of 10% at the end of the curve.

4.5.1.7 Distribution of combined Soil transmitted helminths at National, provincial, district and school levels

Overall, the national prevalence of soil transmitted helminthiasis (*Ascaris*, hookworm and *T. trichiura* combined) was found to be 22.0% (95% Confidence Interval 19.2-24.8%) and the provincial prevalence rates ranged from 4.3% to 41.9% with the highest and lowest recorded in Northwestern and Southern Provinces respectively (Table 4-3). Northwestern (41.9%) and Western (39.1%) provinces were found to have significantly higher rates than all other province as shown in Figure 4-36 and 4-37. The next highest provinces were Northern (26.5%), Copperbelt (25.8%) and Muchinga. No province was found to be non-endemic. Generally, the prevalence of each STH (*A. lumbricoides*, hookworm and *T. trichiura*) outlined in Table 4-3 shows that prevalence of hookworm was significantly higher than *A. lumbricoides* and *T. trichuris* in all the provinces except Copperbelt where *A. lumbricoides* was higher than the two species (Table 4-3).

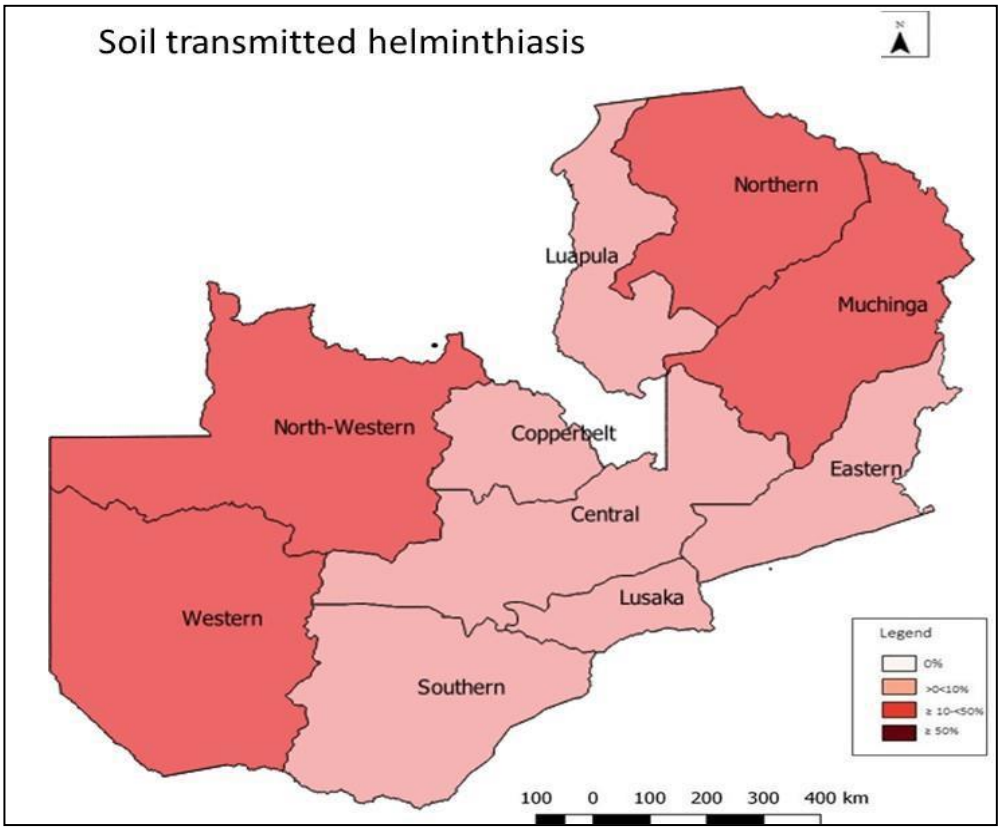


Figure 4-36 Map of combined or overall soil transmitted helminths provincial prevalence in the study population

At the provincial level half, the country has low prevalence and the other moderate

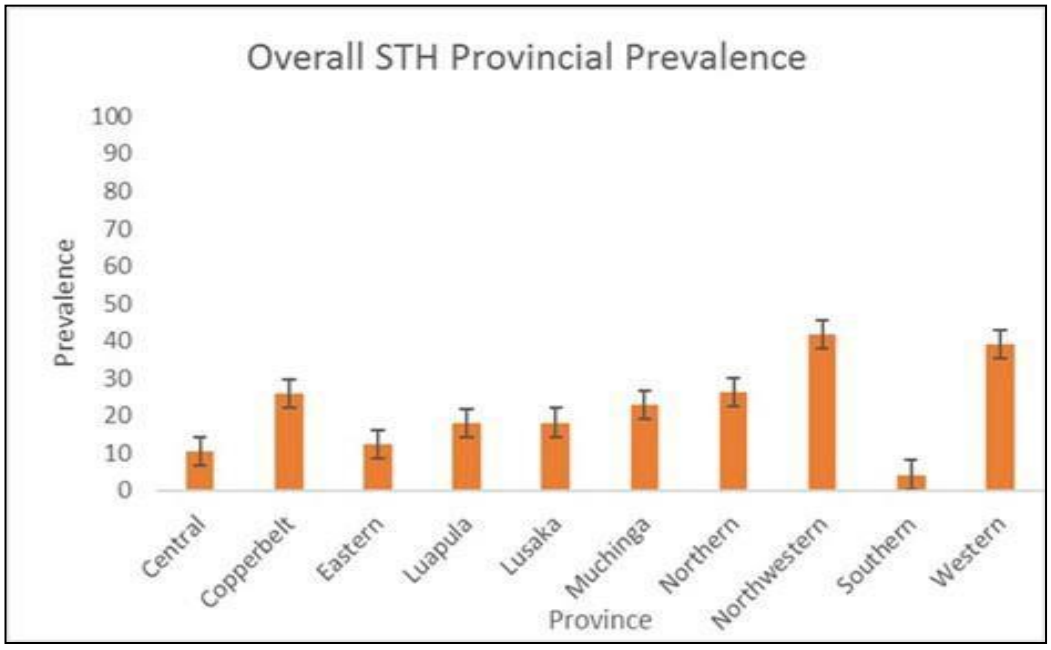


Figure 4-37 Graphs showing the provincial prevalence of soil transmitted helminths in the study population

At district level, the overall prevalence rates for STH ranged from 0.8 to 54.6% (Figure 4-38 and 4-39) with the significantly high rates in Mwinilunga (54.6%), Mufulira (50.7%), Chilubi (50.3%), Lukulu & Kasempa (49.8%) each, Milengi (48.8%), Sesheke (48.5%) and Chinsali (42.7%) as shown in Figure 4-39. Significantly low rates were found in Itezhi Tezhi (0.8%), Livingstone (1.2%), Geembe (1.4%), Kabwe (1.8%), Mumbwa (2.3%), Siavonga (2.3%), Namwala (2.5%) and Kazungula (2.6%). None of the districts was found without any trace of STH.

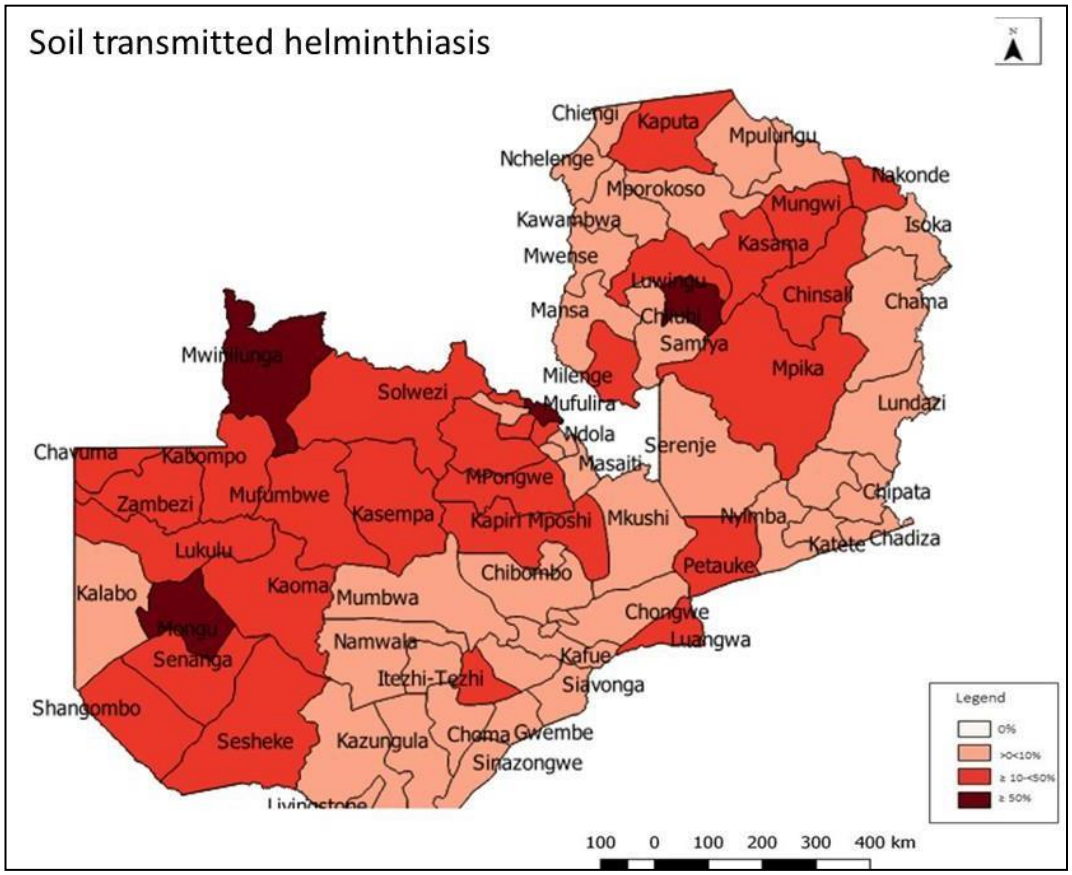


Figure 4-38 Map showing the overall soil transmitted helminthiasis prevalence distribution at the district level in the study population

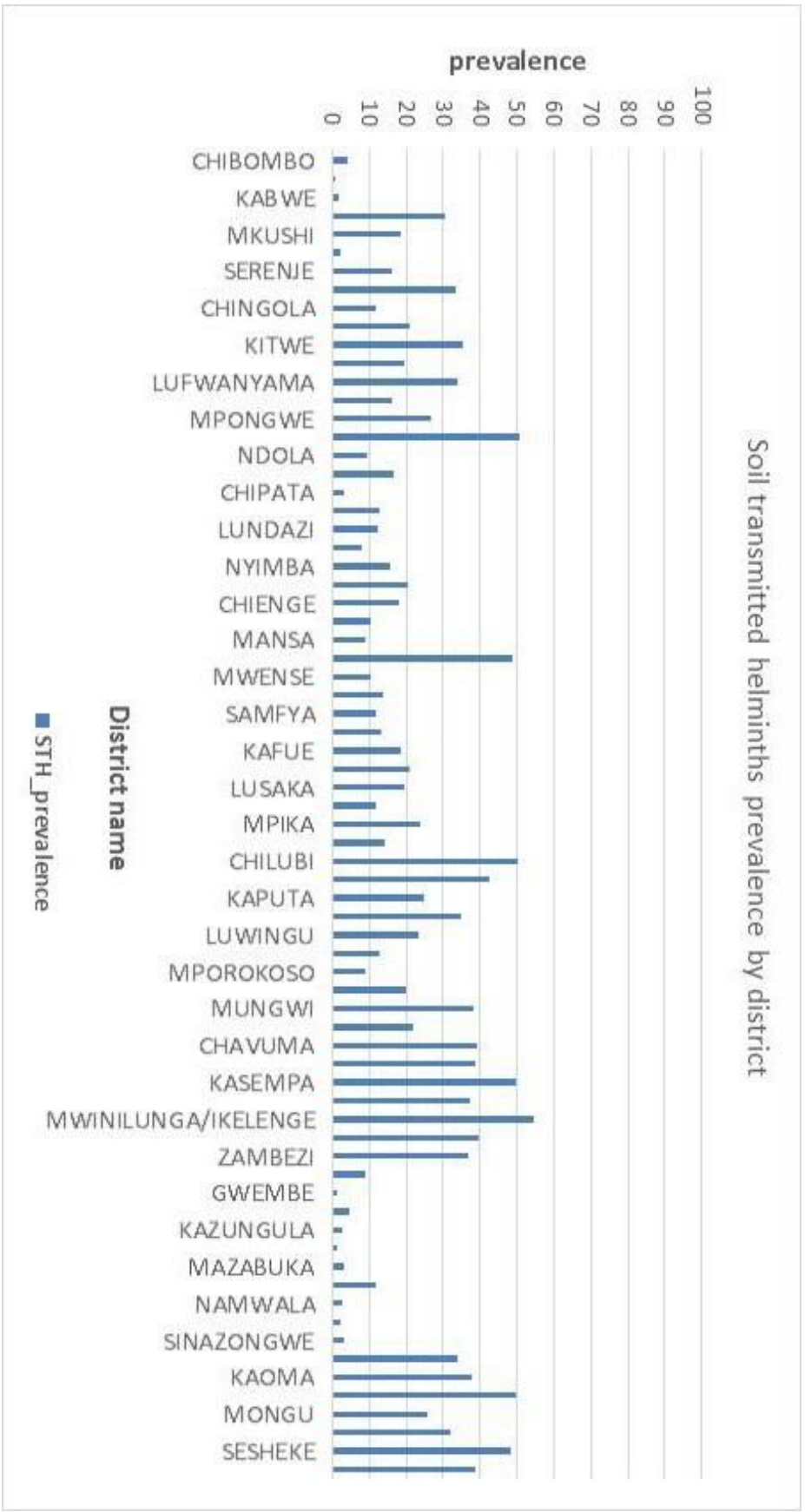


Figure 4-39 Graphs showing the prevalence of soil transmitted helminthiasis at district level according to provinces

The 20 schools target was met in 65.3% of the districts, 19 schools in 12.5% and 18 schools in 8.3% districts. 17, 12 and 11 schools were sampled in 1.4% (1 district each) while 15 and 10 schools were sampled in 5.6% and 4.2% districts respectively like for SCH. The lowest number of schools sampled in a district was 9 schools in Senanga. Overall STH point prevalence or school prevalence ranged from 0-90% (Figure 4-40) with the highest rates recorded at 2 schools (1 in Chilubi and the other in Sesheke). These were followed by schools with 82.7% in Kasempa and 80% at 2 schools (1 in Mufulira and the other in Zambezi). Further, 11.6% of schools (157 schools) had a prevalence rate over 50% considered as high endemic, 34.1% (460 schools) had moderate endemicity and 35.7% (481 schools) had low endemicity. 18.6% (251 schools) were non-endemic at 0% prevalence rate. The plotof school prevalence of STH across 1349 schools with a mean prevalence of 21.5% ranked in ascending order highlighted a well-known pattern of over dispersion in Figure 4-41. 24.6% of the schools (332 of 1349 schools) reported endemicity of bothspecies (*A. lumbricoides* and Hookowrm) but only 0.0004% of the individuals sampled had co-infection. The co-endemic schools for *A. lumbricoides* and hookworm were distributed across 52 districts (72%) with the highest number in Milengi (95.0%), Kasama (94.77), Luangwa (80.0%), Mpulungu (75.0%), Lusaka (70.0%) and Lufwanyama (68.4%) and Nyimba (65.0%) schools each.

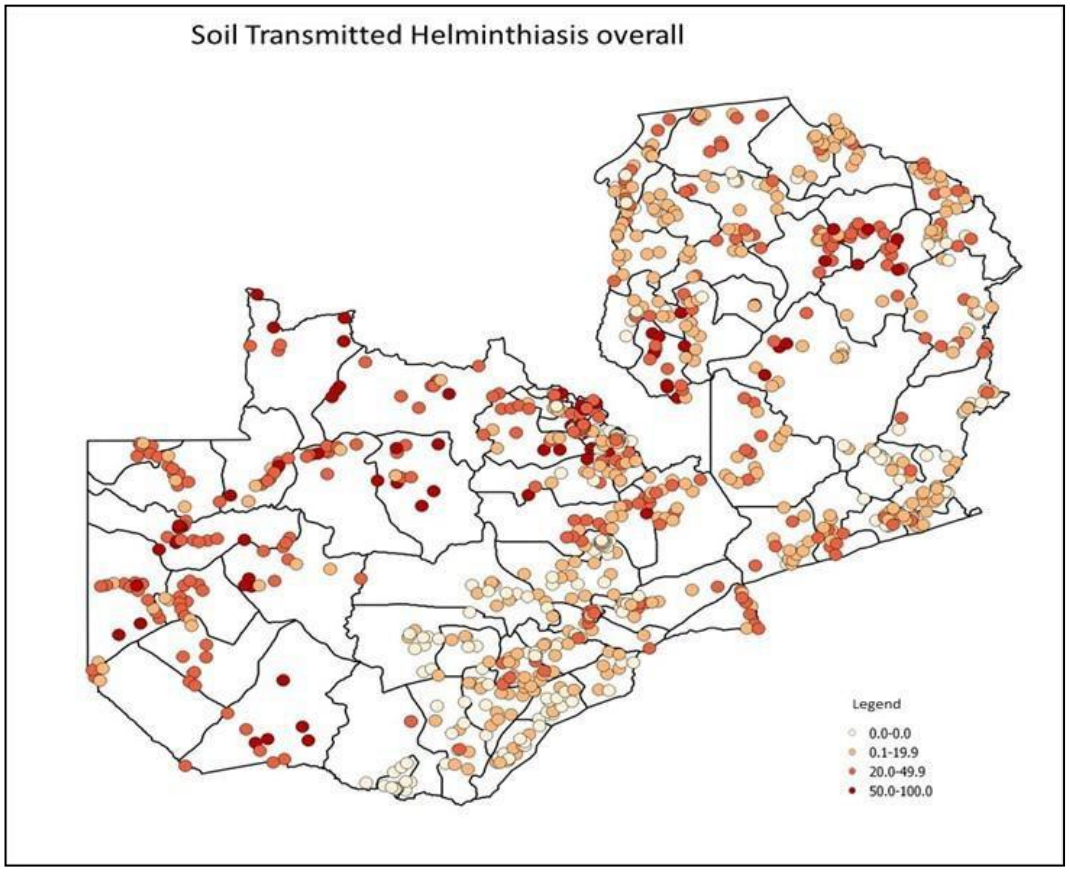


Figure 4-40 Point prevalence map for overall soil transmitted helminths in the study population of Zambia

The points are the school locations where the study was conducted in the prevalence calculated in the study population

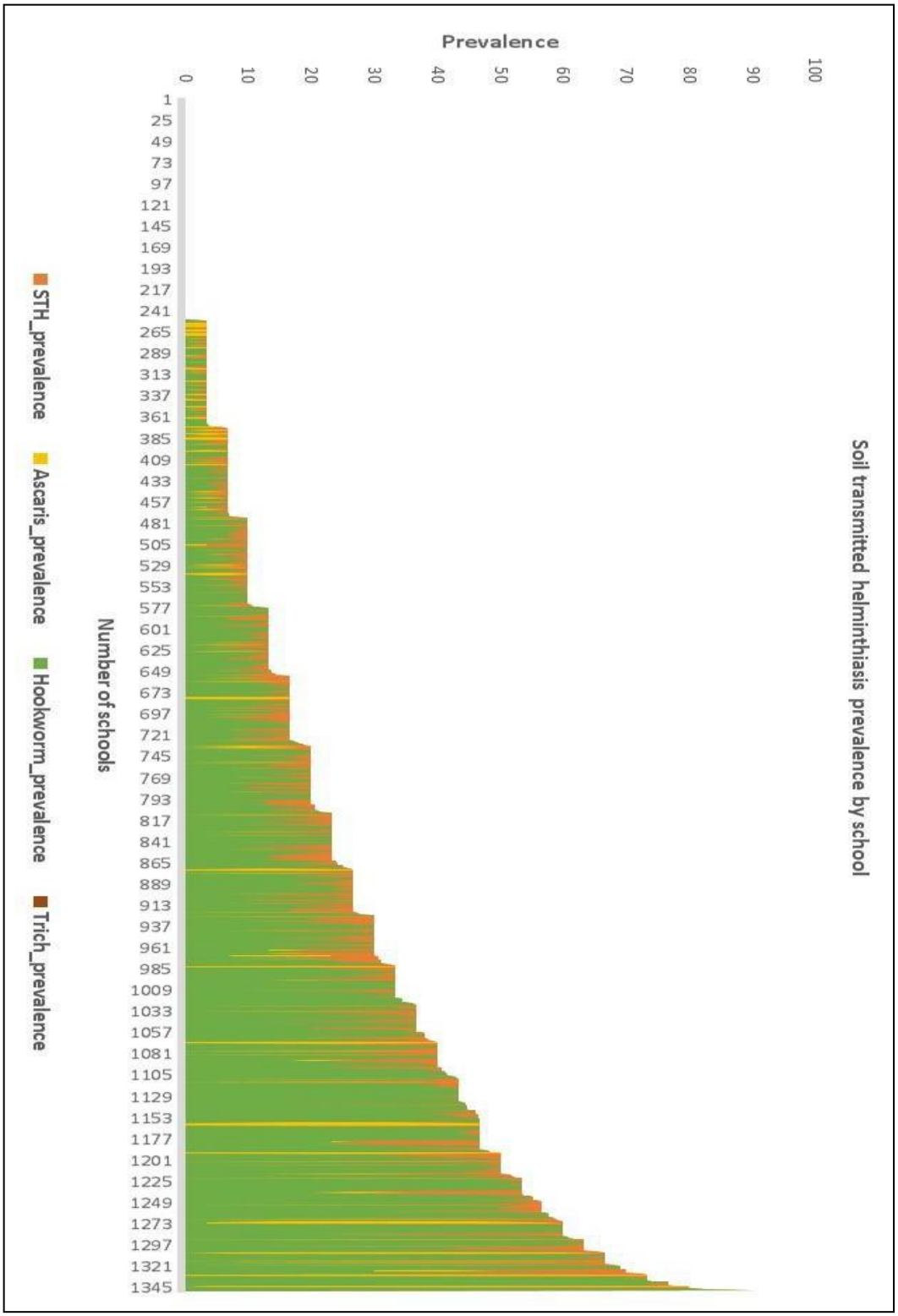


Figure 4-41 Graph showing schools ranked by prevalence for soil transmitted helminths in Zambia

The curve shows ranking of the individual soil transmitted helminth species and co-infection reported at school level. Over 85 % of the schools were endemic for any soil transmitted helminths or combined.

4.5.2 Age and sex distribution

The sample contained 50.3% female and 49.7% male. More children tested positive for hookworm (6805), followed by *S. haematobium* (6206), and *A. lumbricoides* (1688). Generally, the males tested more positive than females with an average rate of 53.4% Table 4-4. Out of all the children tested, 16.8 % males tested positive for S. haematobium compared to 14.2 % and 13.5 % for hookworm compared to 11.7 % females and 13.5 % for hookworm compared to 11.7 % as indicated in Table 4-4. Amongst the females and males that tested positive for *S. haematobium*, a significant number was recorded from Lusaka Province (13.1% and 13.3% respectively) followed by Northwestern (8.5% and 8.8%) and Luapula (7.1% and 7.8%) Provinces. However, Southern Province recorded a higher positive result in males than female (more than 53.6%). A low proportion of both females and males tested positive on the Copperbelt, Northern and Western provinces. Amongst the females and males that tested positive for *S. mansoni*, a significant number was recorded from Northwestern Province (9.6% and 10.4% respectively) followed by Southern (4.1% and 3.9%) and Luapula (2.2% and 2.5%). While low proportions of both females and males tested positive on the Copperbelt, Central and Eastern provinces. Males tested more positive than females with an average rate of 53.0%, 53.4% and 50.4% for *A. lumbricoides*, hookworm and *T. trichiura*, respectively (Table 4-4). Overall, the Pearson Chi-Square indicates that there was no statistical difference between gender with *S. mansoni* (X^2=1.598[a], p=0.45) and *T. trichuris* (X^2=0.010[a], p=0.995) infection; however, there was statistical difference between gender and *S. haematobium* (X^2=132.374[a], p=0.000), hookworm (X^2=42.506[a], p=0.000) and *lumbricoides* (X^2=7.124 p=0.028) indicated in Table 4-5. The strength of association between the variables for sex with type of infection using Phi and Cramer's V revealed a strong association for *S. haematobium* p=0.000, hookworm p=0.000 and *A. lumbricoides* p=0.028.

With regards to age distribution, most of the participants in the study were aged between 10-12 years (53.1%) followed by the 13-15 years (33.6 %) (Table 4-4). The 10-12 years age group had high positive *S. haematobium* results at 78.6% followed by ≥15 years at 14.3% and below 10 years old at 8.1%. However, Overall, the Pearson Chi-Square indicates that there was no statistical difference between age group with *S. haematobium* X^2=4.785[a], p=0.310, and *T. trichuris* X^2=6.657[a], p=0.155

infection; however, there was statistical difference between age group and *S. mansoni* (X^2=333.388[a], p=0.000), hookworm (X^2=353.108[a], p=0.000) and *A. lumbricoides* (X^2=94.965 df=4, p=0.000) Table 4-5. The strength of association between the variables for sex with type of infection using Phi and Cramer's V revealed a strong association for *S. mansoni*, p=0.000, hookworm p=0.000 and *A. lumbricoides* p=0.028. The analysis of the central tendency in the study population revealed a mean age was 12.13, median age 12, mode 12 with a standard deviation of 2.153 (Table 4-6). The age range in the sample was from 0-30 years.

Table 4-4 Age and sex distribution of schistosomiasis and soil transmitted helminths in the study population

Variable	Category	% N	*S. mansoni*	*S. haematobium*	Hookworm	*A. ascaris*	*T. trichuris*
Age range	**0-4**	0.1	7.7	0	0	0	0
	5-9	8.7	1.1	14.9	6.1	2.6	1
	10-12	53.1	1.7	16.2	11.4	5.8	0.3
	13-15	33.6	2.5	15.5	14.5	4.8	0.3
	>15	4.6	6.9	8.9	24.4	1.5	0.4
Sex	**M**	49.7	16.8	2.2	13.5	5.3	0.3
	F	50.3	14.2	2.1	11.7	4.7	0.2

Table 4-5 Pearson Chi-Square test to compare statistical significance in difference test results of age range and sex shown in Table 4-4.

Variable	Category	Pearson X^2	*Df*	*p-value*	Phi	*Cramers's V*
Age range	***S. heamatobium***	4.785[a]	4	0.310	0.310	0.310
	S. mansoni	372.766[a]	4	0.000	0.000	0.000
	Hookworm	353.108[a]	4	0.000	0.000	0.000
	A. lumbricoides	94.965[a]	4	0.000	0.000	0.000
	T. trichuris	6.657[a]	4	0.155	0.155	0.155
Sex	***S. heamatobium***	32.373[a]	2	0.000	0.000	0.000
	S. mansoni	1.598[a]	2	0.450	0.450	0.450
	Hookworm	42.506[a]	2	0.000	0.000	0.000
	A. lumbricoides	7.124[a]	2	0.028	0.028	0.028
	T. trichuris	0.010[a]	2	0.995	0.995	0.995

Table 4-6 Central Tendency in the study population

Variable	Category	
Age	Mean	12.13
	Median	12
	Mode	12
	Standard Deviation	2.153
	Range	0-30

4.5.3 Proportion of positive schools for SCH and STH

Out of the 1349 scools sampled 64 % had positive cases of schistosomiasis and 81 % for soil transmitted helminthiasis. 58 % of the schools reported cases of *S. haematobium*, 23 % for *S. mansoni* while 72 % had children with hookworms, 34 % with *A. lumbricoides* and only 6 % for *T. trichiuria* as shown in Figure 4-42 and 4-43.

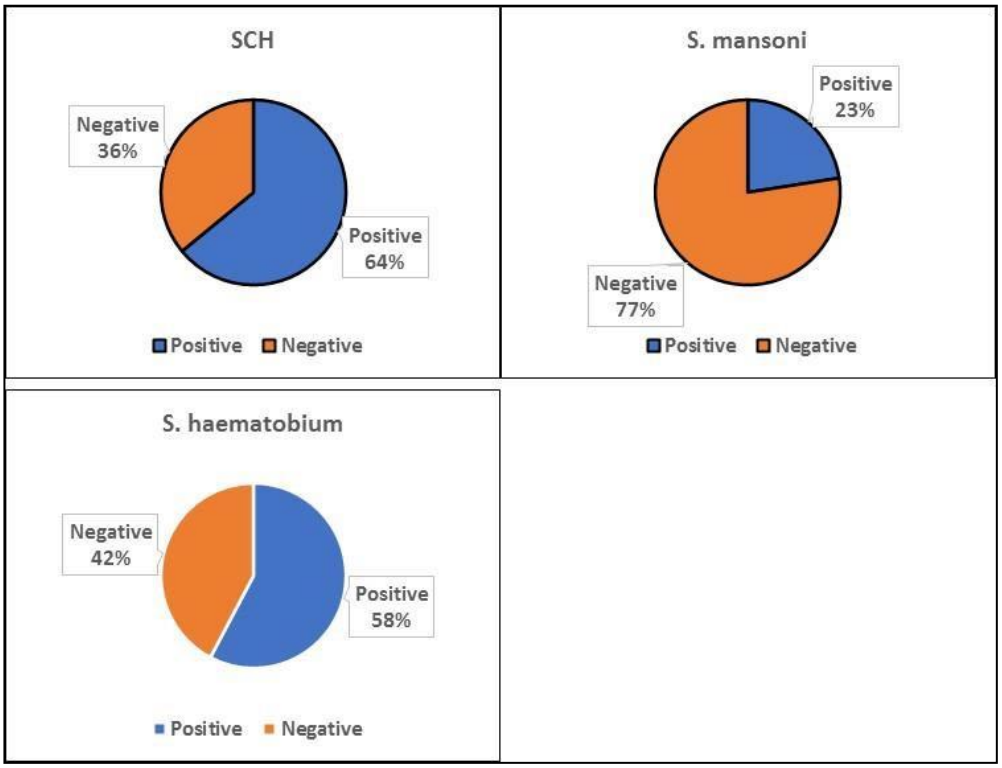


Figure 4-42 Proportion of schools with any schistosomiasis in the study population

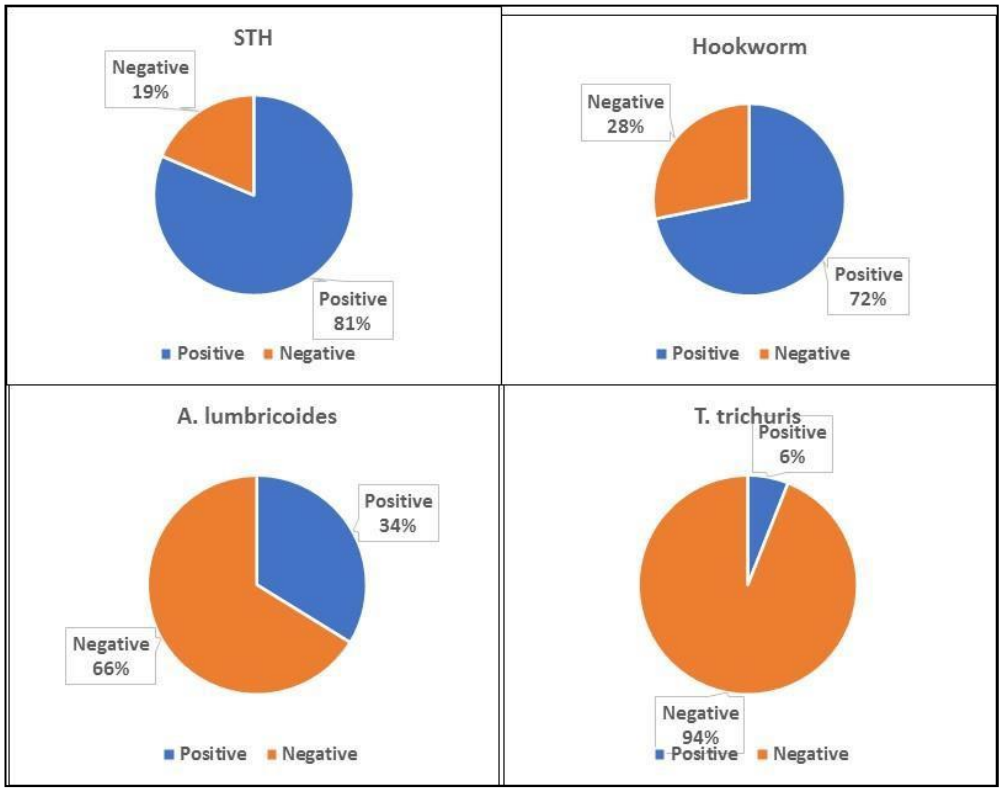


Figure 4-43 Proportion of schools with any soil transmitted helminths, *A. lumbricoides*, hookworm and *T. trichiura* in the study population

81% schools are endemic for STH, 72 of schools for hookworm, 34% for Ascaris and 6 % trichuris

4.5.4 Comparison of dipstick and urine filtration

The Pearson Chi-Square test analysis revealed that based on the 2x2 contingency table (Table 4-7), the observed frequencies of the urine dipstick results and urine filtration results were not statistically different from the expected frequencies (X^2=27673.800[a], df=1, p=0.000 2-tailed) with a significant Continuity correlation (X^2=27667.863) and likelihood ratio (Table 4-8). The Phi Cramer's V test in Table 4-8 indicates an association equivalent to 0.831 between urine dipstick results and the urine filtration results which is also proved by the Pearson Correlation with the same significant at the 0.01 level (2-tailed) indicated in the same Table (Table 4-8). What I would have expected if the Null Hypothesis were true were 1138 people testing positive for both test types and not 5800 people that tested positive. The findings therefore reject the null hypothesis, the observed frequencies are statistically different from the expected frequencies.

Table 4-7 Crosstabs for Urine dipstick and Urine filtration

		Urine filtration		
		Negative	Positive	Total
Urine dipstick results	Negative	32206	406	32612
	Positive	1527	5800	7327
Total		33733	6206	39939

Table 4-8 Pearson Chi-Square test and Pearson Correlation on Urine dipstick and urine filtration results

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	27673.800[a]	1	.000		
Continuity Correction[b]	27667.863	1	.000		
Likelihood Ratio	22633.645	1	.000		
Fisher's Exact Test				.000	.000
N of Valid Cases	39939				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 1138.52.

b. Computed only for a 2x2 table

Symmetric Measures

		Value	Approximate Significance
Nominal by Nominal	Phi	.832	.000
	Cramer's V	.832	.000
N of Valid Cases		39939	

Correlations

		Urine dipstick results	Urine filtration
Urine dipstick results	Pearson Correlation	1	.811**
	Sig. (2-tailed)		.000
	N	39939	39939
Urine filtration	Pearson Correlation	.811**	1
	Sig. (2-tailed)	.000	
	N	39939	39939

**. Correlation is significant at the 0.01 level (2-tailed).

4.5.5 Spatial clustering and environmental analysis

Spatial clustering

There were statistically significant hot spot clusters for *S. haematobium* in Lusaka and Luapula provinces with 99% confidence level (α=0.001; Z-score >2.58 Std. Dev) in Figure 4-44 and significantly cold spots at 99% Confidence Level (α=0.001; Z-score <-2.58 Std. Dev) on the Copperbelt and Southern Province. The significantly hot spot clusters for *S. mansoni* were seen in Northwestern and Southern Provinces while the significant cold spots were on the Copperbelt Province as shown in Figure 4-45. Most of the country had very low to no significant clustering. The combined schistosomiasis hot and cold spot clusters (Figure 4-46) were in Lusaka, Southern part of Luapula and Northwestern Provinces. While the cold spots were on the Copperbelt, Southern and Northern Provinces.

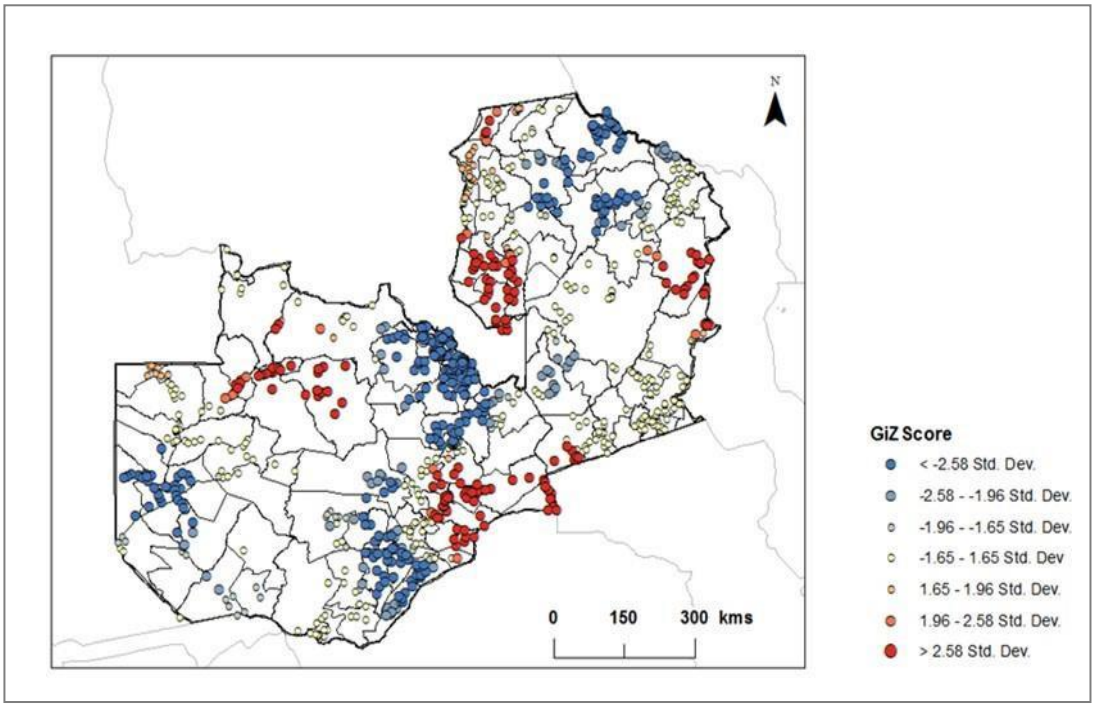


Figure 4-44 Maps of spatial clustering of cold and hot spots *S. haematobium*,

The hot spots of *S. haematobium* in the study sites sampled. The red dots are the hot spot clusters while the blue dots are cold spot clusters for S. haematobium.

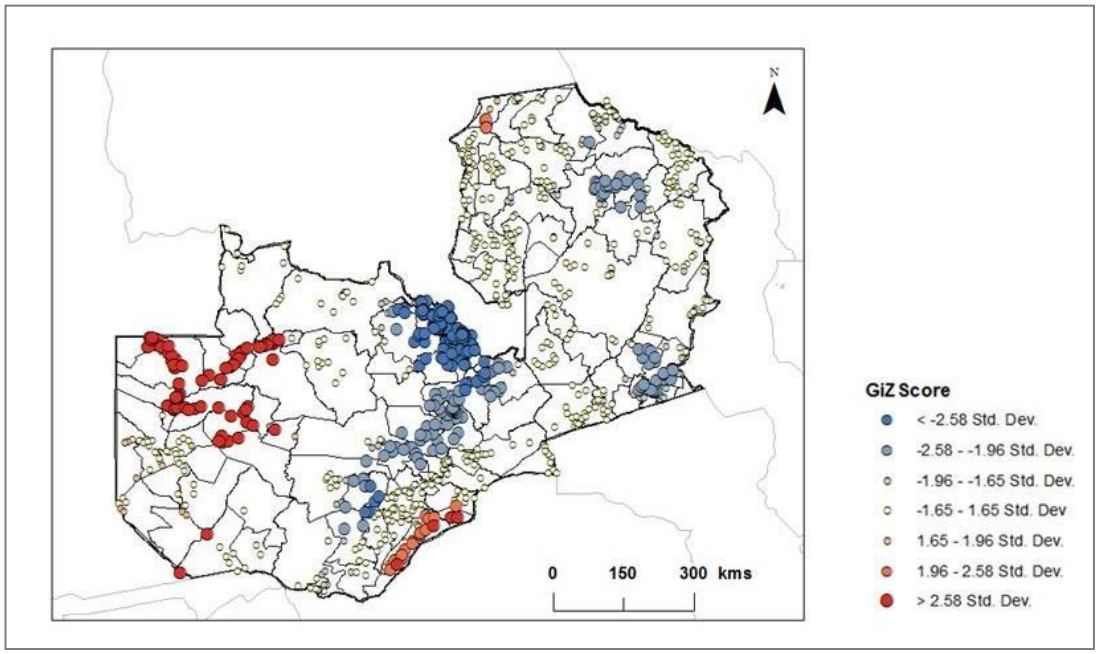


Figure 4-45 Maps of spatial clustering of cold and hot spots for *S. mansoni*

The hot spots of *S. mansoni* in the study sites sampled. The red dots are the hot spot clusters while the blue dots are cold spot clusters for *S. mansoni*

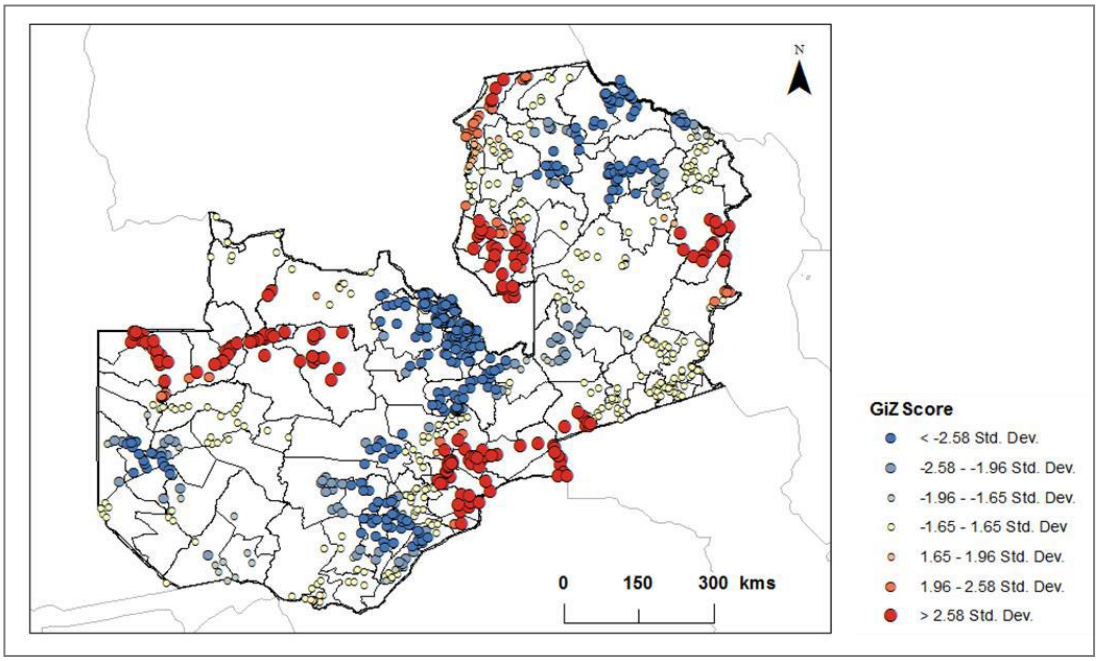


Figure 4-46 Maps of spatial clustering of cold and hot spots for schistosomiasis,

The hot spots of overall schistosomiasis in the study sites sampled. The red dots are the hot spot clusters while the blue dots are cold spot clusters for Schistosomiasis

With STH, the hotspot clusters for hookworm were statistically significant at the 99% Confidence Level (α=0.001; Z-score >2.58 Std. Dev) in Western, Northwestern and Northern Provinces (Figure 4-47). The cold spot clusters were seen in the Southern, Copperbelt, Eastern and Luapula Provinces statistically significant with a 99% Confidence Level (α=0.001; Z-score <-2.58 Std. Dev) while for *Ascaris* the statistically significant hot spot clusters at 99% confidence level were on the Copperbelt and Luapula Provinces and statistically significant cold spot clusters at 99% Confidence Level in Southern, Eastern and northern part of Luapula Provinces indicated in Figure 4-48. Most of the remaining spots did not belong to clusters and were randomly distributed.

The findings, based on the Getis -Ord Gi* statistics, that SCH and STH had spatially localised transmission rejects the assumption by the null hypothesis that spatial distribution is random in Zambia. All the four endemic species subjected to spatial statistical analysis highlighted the statistically significant hot and cold spot clusters in the country at 99% Confidence level with the GIZ score of >2.58 and <-2.58 Standard deviation respectively.

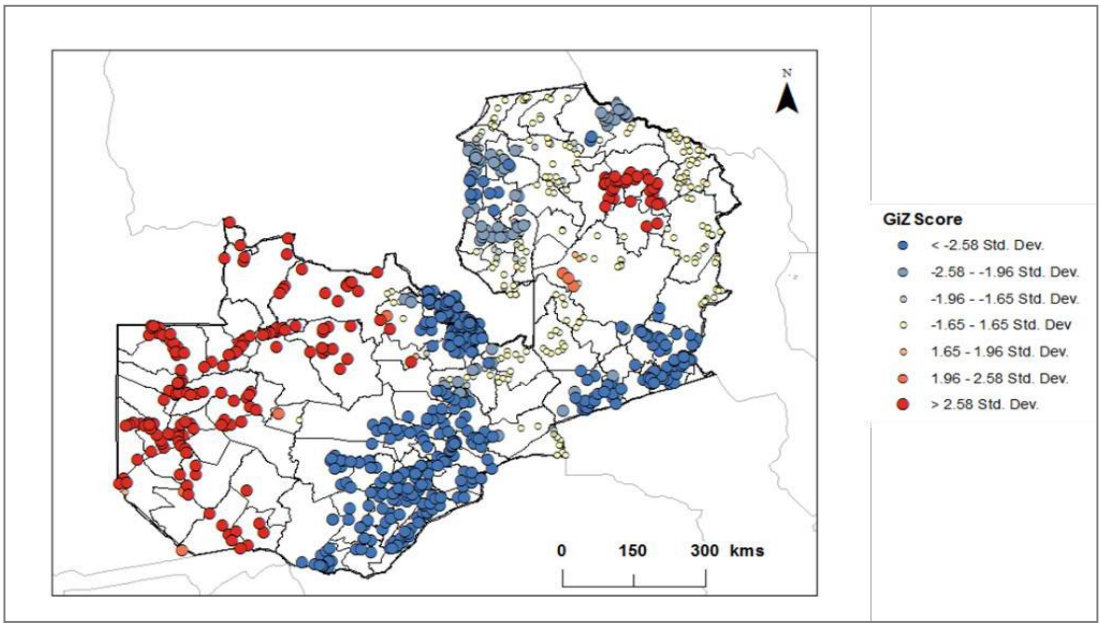


Figure 4-47 Maps of spatial clustering of cold and hot spots for hookworm

The hot spots of hookworm in the study sites sampled. The red dots are the hot spot clusters while the blue dots are cold spot clusters for hookworm

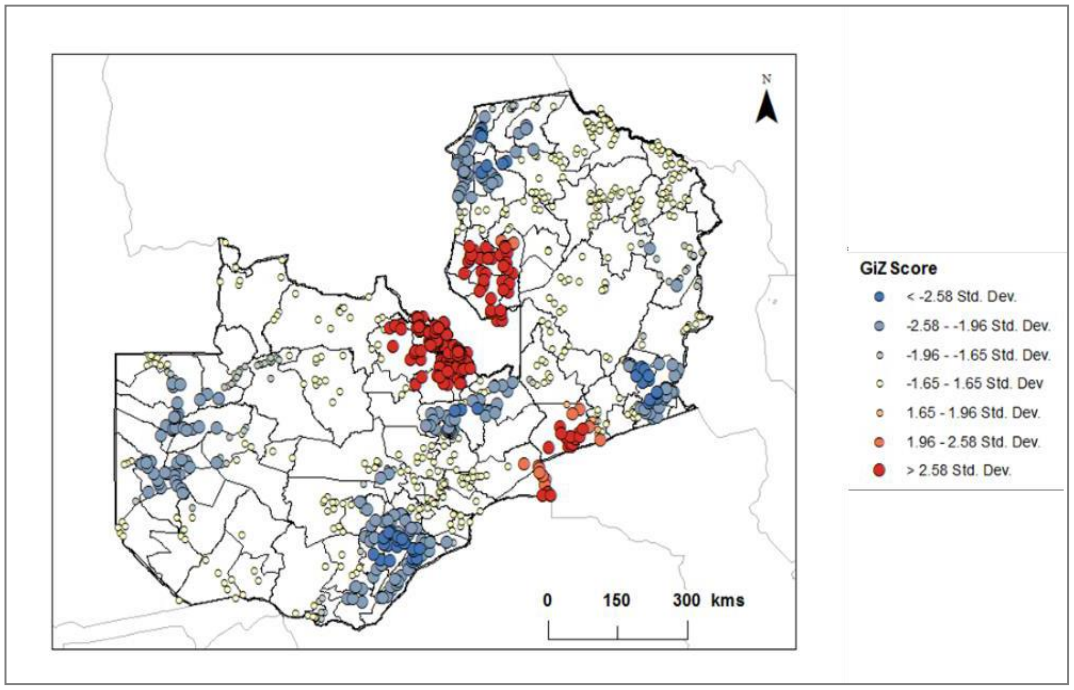


Figure 4-48 Maps of spatial clustering of cold and hot spots for *A. lumbricoides*

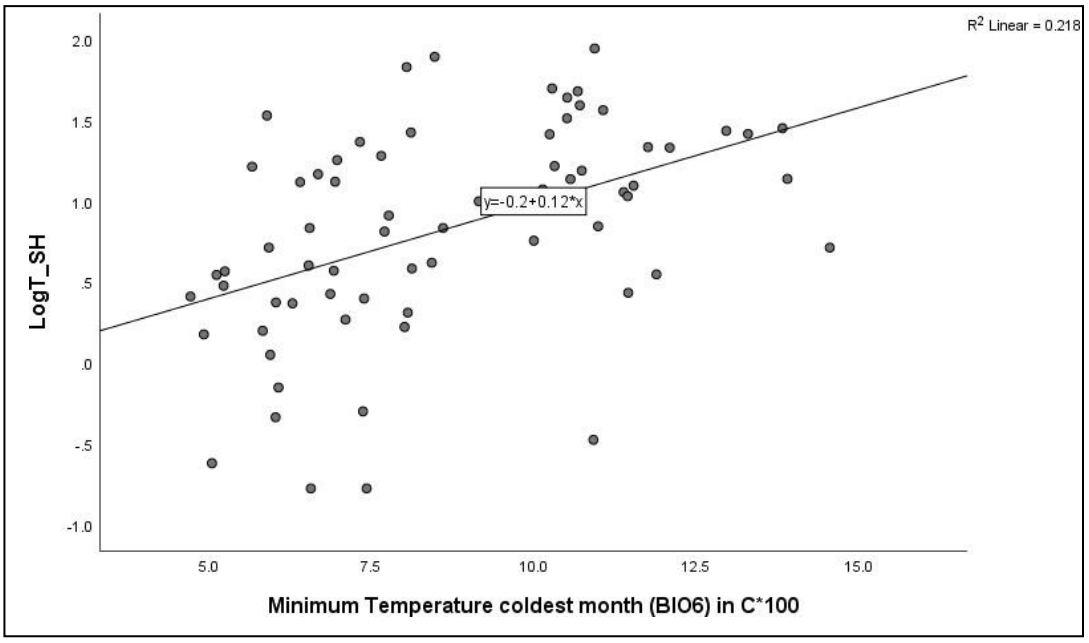
The hot spots for *A. lumbricoides* in the study sites sampled. The red dots are the hot spot clusters while the blue dots are cold spot clusters for ***A. lumbricoides***

4.5.6 Bivariate correlations of environmental predictors associated with distribution of schistosomiasis and soil transmitted helminths species

Four independent variable predictors (elevation, temperature, precipitation, and soil types) were plotted against the independent variable prevalence of SCH and STH species. Scatter plots with linear correlations are shown in Figure 4-49 a and b for *S. haematobium* with minimum temperature coldest month positive linear association, and annual temperature with a negative linear association. Figure 4-50, negative linear association between Log *S. mansoni* prevalence and precipitation wettest month. Figures 4-51, 4-52 and 4-53 also indicate linear association between Log hookworm with silt topsoil (negative), Log *A. lumbricoides* with clay topsoil and *T. trichuris* with minimum temperature. The correlation was further tested for association using Pearson Correlation Coefficient (r). The results summarised in Table 4-9 has shown 7 negative coefficient correlation and 8 positive coefficient correlation indicating mild to moderate correlations. The 2-tailed significance value for the 15 correlations in my study ranged from .002 to .05. with most of our correlations highly significant, not just a function of random sampling error as

summarised in Table 4-9. Despite the mild to moderate correlations, the significance is very high for these findings as my study has enough statistical power to identify even very weak effects. Another important finding was that several proposed predictors did not have any association with the changes in the prevalence of the different species due to their larger insignificant p-values.

a)



b)

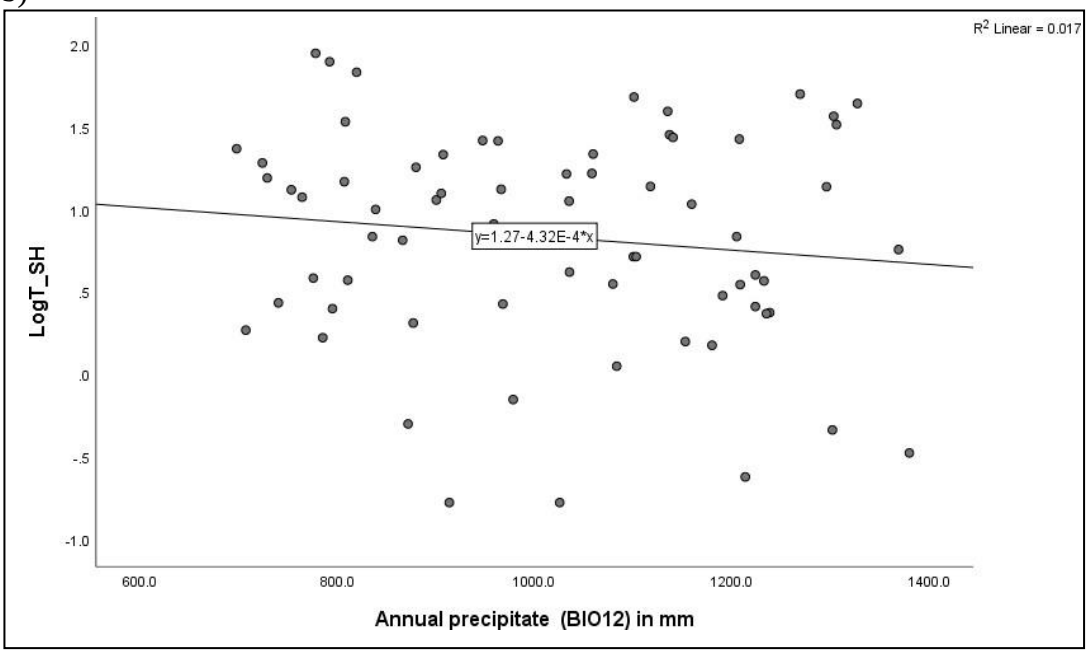


Figure 4-49 Scatter plot showing the association between Log transformed data for *S. haematobium* and a) Minimum temperature coldest month and b) annual precipitation

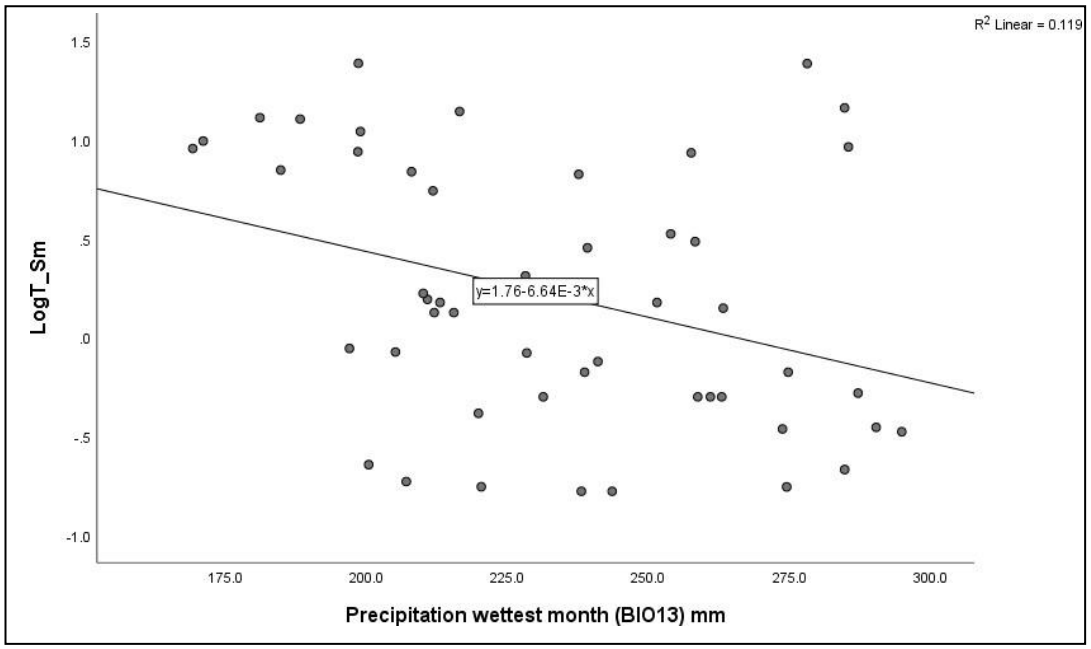


Figure 4-50 Scatter plot showing the association between Log transformed data for *S. mansoni* and precipitation wettest month

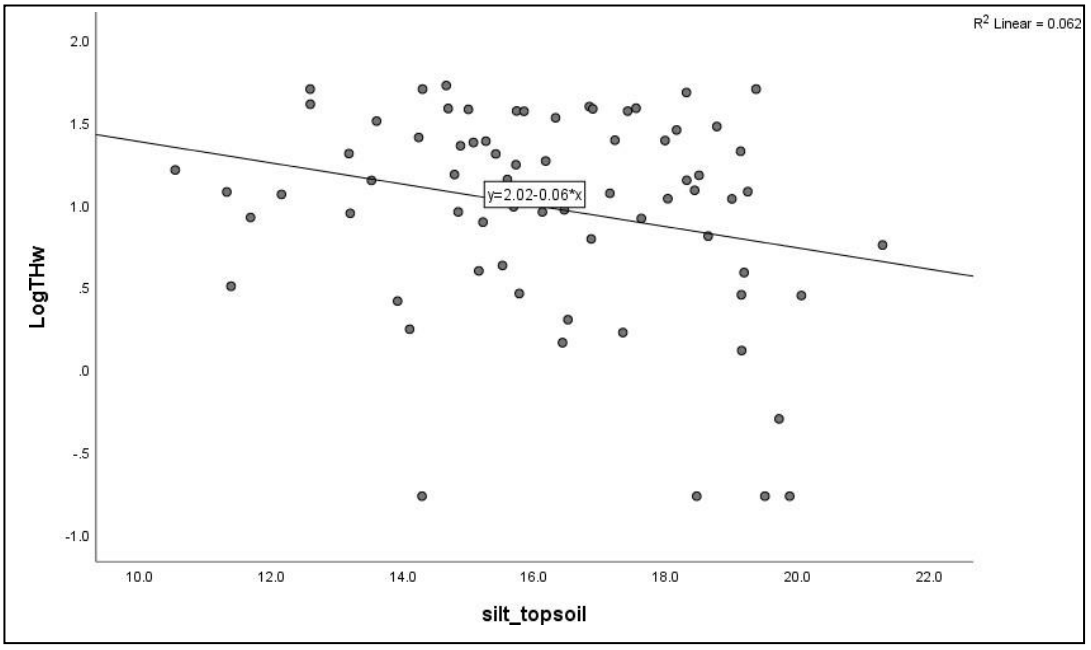


Figure 4-51 Scatter plot showing the association between Log transformed data for Hookworm and silt-top soil

c)

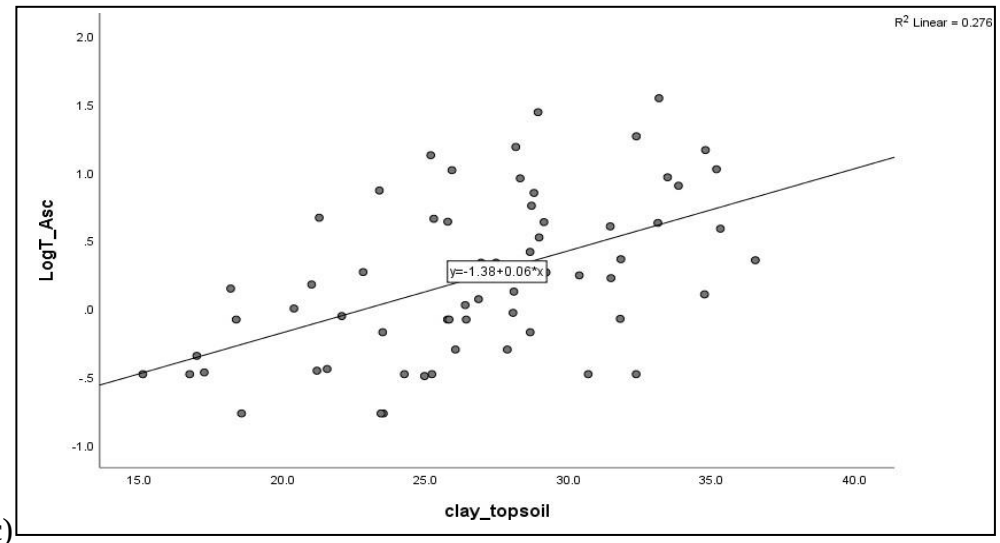


Figure 4-52 Scatter plot showing the association between Log transformed data for *A. lumbricoides* with a) minimum temperature coldest month, b) annual precipitation and c) clay-top soil,

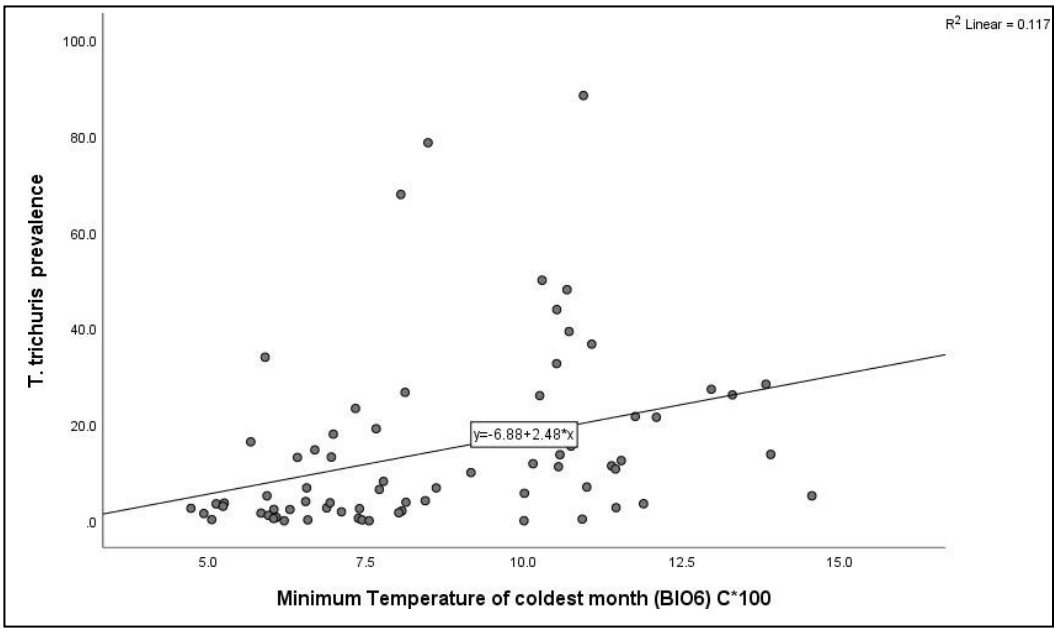


Figure 4-53 Scatter plot showing the *T. trichuris* prevalence and minimum temperature of coldest month

Table 4-9 Summary Table of the Pearson's Correlations between the predictors and the SCH and STH species

Name	Description	Source (extracted at 5km resolution)	Species	Pearson coefficient Correlation	2-tailed Significance value
BIO1	Mean annual Temperature	http://www.worldclim.org/	Hw	0.281*	0.017
BIO5	Maximum Temperature hottest mo	http://www.worldclim.org/	S.h Hw	0.264* -0.335**	0.025 0.004
BIO6	Minimum temperature coldest mo	http://www.worldclim.org/	Asc	-0.289*	0.014
BIO12	Annual Precipitation	http://www.worldclim.org/	Asc	0.321**	0.006
BIO13	Precipitation wettest month	http://www.worldclim.org/	T.t	0.306**	0.009
			Asc Hw	0.353** -0.232*	0.002 0,05
BIO14	Precipitation driest Mo	http://www.worldclim.org/	Hw	0.312**	0.008
Clay	Clay topsoil	ftp://africagrids.net/	S.h Hw	-0.278* 0.325**	0.018 0.005
Silt	Silt topsoil		Hw	0.288*	0.014
Sand	Sand topsoil		Hw	0.308**	0.008
pH	pH topsoil		Asc T.t	-0.331** -0.346**	0.004 0.003

Key: S.h=S. haematobium; S.m= S.mansoni; T.t= T. trichuris; Hw= hookworm, Asc=A. lumbricoides; mo=month

4.5.7 Multivariate analysis of environmental predictors associated with distribution of schistosomiasis and soil transmitted helminth species

Multivariant analysis performed using General Linear Model, Post Hoc tests and Post Hoc multiple comparisons for observed means of STH and SCH species and independent predictors and their variable categories, produced the following results:

4.5.7.1 Annual Mean Temperature

Table 4-10 shows the mean and standard deviation for prevalence data split according to the categories of the annual mean temperature. The highest mean prevalence (27.4 %, Std Dev. 16.296) was seen under good temperature for hookworm (Table 4-10). The multivariate test revealed a statistically significant difference in prevalence of the SCH and STH species for the annual mean temperature $F(10, 128)=5.364$, $p<0.0005$; Wilk's $\Lambda=0.285$, partial eta squared $\eta^2=.29$ Table 4-11a. The univariate ANOVAs test (Table 4-11b) performed to determine how prevalence of SCH and STH species differ for annual mean temperature indicated a statistically significant effect on *A. lumbricoides*, ($F(2, 69)=9.952$, $p<0.0005$; $\eta^2=.224$), hookworm ($F(2, 69)=3.585$, $p=0.033$; $\eta^2=.094$), *T. trichuris* ($F(2, 69)=5.871$, $p=0.004$; $\eta^2=.145$), and S. haematobium ($F(2, 69)=4.861$, $p=0.011$; $\eta^2=.123$). However, further analysis for multiple comparisons in mean difference between the scores of the categories under the independent variable, annual mean temperature, for each species using Turkey HSD test (Table 4-12), showed statistically significant difference for cold-good, cold-very hot, ($p<0.0005$) but not for good-very hot ($p=0.522$) for *A. lumbricoides*. For hookworm, the mean scores were statistically significant only between good and very hot ($p=0.025$) but not between cold and good ($p=0.896$), and cold and very hot ($p=0.173$) while the mean scores for *T. trichuris* were statistically significant between cold and good ($p=0.010$); and cold and very hot ($p=0.007$) and but not between good and very hot ($p=0.608$). Only between good and very hot ($p=0.039$) were statistically significant for *S. haematobium* and none of the scores for *S. mansoni* were statistically significant.

One-way MANOVA was statistically significant $p<0.0005$ and therefore can conclude that prevalence of *Schistosoma* and soil transmitted helminths species were significantly dependent on annual mean temperature. In this case we reject the null

hypothesis that annual mean temperature has no effect on the prevalence of *Schistosoma* and soil transmitted helminths.

Table 4-10 Descriptive statistics for SCH and STH prevalence split by categories of annual mean temperature

Annual Mean Temperature	Haematobium Mean; Std Dev	Mansoni Mean; Std Dev	Hookworm Mean; Std Dev	Ascaris Mean; Std Dev	Trichuris Mean; Std Dev
Cold	6.41;7.751	2.18;6.634	16.9;17.312	11.5;12,785	0.75;1.011
Good	19.25;20.793	2.82;5.136	14.8;13.123	3.0;5.050	0.22;0.443
Very hot	5.19;5.528	4.50;4.538	27.4;16.296	0.67;0.713	0.05;0.110
Total	14.5;18.346	2.99;5.31	17.3;14.983	4.2;7.549	0.29;0.594

Table 4-11Table Multivariate Tests for the one-way MANOVA and Post Hoc Tests for SCH and STH species and the independent variable - annual mean temperature

a) Table Multivariate Tests for the one-way MANOVA

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Annual Mean Temperature	Pillai's Trace	.578	5.360	10.000	132.000	.000	.289
	Wilks' Lambda	.501	5.364[b]	10.000	130.000	.000	.292
	Hotelling's Trace	.838	5.365	10.000	128.000	.000	.295
	Roy's Largest Root	.555	7.327[c]	5.000	66.000	.000	.357

b) Univariant ANOVA **Tests of Between-Subjects Effects**

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Annual Mean Temperature	Asc_Prevalence	905.906	2	452.953	9.952	.000	.224
	HW Prevalence	1500.277	2	750.138	3.585	.033	.094
	TT Prevalence	3.654	2	1.827	5.871	.004	.145
	SH_Prevalence	2951.052	2	1475.526	4.861	.011	.123
	SM_Prevalence	37.012	2	18.506	.649	.526	.018
Error	Asc Prevalence	3140.603	69	45.516			
	HW Prevalence	14439.719	69	209.271			
	TT Prevalence	21.475	69	.311			
	SH_Prevalence	20945.651	69	303.560			
	SM_Prevalence	1968.354	69	28.527			

a. R Squared = .224 (Adjusted R Squared = .201)

b. R Squared = .094 (Adjusted R Squared = .068)

c. R Squared = .145 (Adjusted R Squared = .121)

d. R Squared = .123 (Adjusted R Squared = .098)

Table 4-12 Summary of Multiple comparisons with Tukey's HSD post-hoc tests

Annual Mean Temperature – mean score			
Category	Cold & good P-value	Good & very hot P-value	Cold & very hot p-value
A. Lumbricoides	<0.0005	0.522	<0,0005
Hookworm	0.896	0.025	0.173
T. trichuris	0.010	0.608	0.007
S. haemtobium	0.055	0.039	0.983
S. mansoni	0.919	0.602	0.526

4.5.7.2 **Minimum temperature coldest month**

The descriptive statistics in Table 4-13 provides the mean and standard deviation for the five dependent variables split by the three variable categories for minimum temperature coldest month. The highest mean prevalence (27.4 %, STD Dev. 16.296) was seen under very cold temperature for hookworm. There was a statistically significant difference in prevalence of the SCH and STH species based on multivariate tests on minimum temperature coldest month $F(10, 130)=2.987^{b}$, $p<0.002$; Wilk's $\Lambda=0.661$, partial eta squared $\eta^2=19$ in Table 4-14a. The univariate ANOVAs test (Table 4-14b) performed to determine how prevalence of SCH and STH species differ for minimum temperature coldest month revealed a statistically significant effect on *S. haematobium*, ($F(2, 69)=6.843$, $p<0.002$; $\eta^2=.17$) and hookworm ($F(2, 69)=3.502$, $p=0.036$; $\eta^2=.092$). One-way MANOVA was statistically significant p=0.002 and therefore can conclude that prevalence of *Schistosoma* and soil transmitted helminths species were significantly dependent on minimum temperature coldest month specifically for *S. haematobium* andhookworm. In this case we reject the null hypothesis that minimum temperature coldest month has no effect on the prevalence of *Schistosoma* and soil transmitted helminths.

Table 4-13 Descriptive statistics for SCH and STH prevalence split by categories of minimum temperature coldest month

Minimum Temperature coldest Month	**Haematobium Mean; Std Dev**	**Mansoni Mean; Std Dev**	**Hookworm Mean; Std Dev**	**Ascaris Mean; Std Dev**	**Trichuris Mean; Std Dev**
Hot	15.60;18.385	2.72;5.485	15.38;14.11	4.80;8.129	0.34;0.644
Very cold	5.19; 5.528	4.50;4.538	27.4;16.296	0.67;0.713	0.06;0.110
Very hot	67.83;	1.66;	12.16;	10.33;	0.00;
Total	14.5;18.346	2.99;5.31	17.3;14.983	4.2;7.549	0.29;0.594

Table 4-14 Multivariate Tests for the one-way MANOVA and Post Hoc Tests for SCH and STH species and the independent variable – Minimum temperature coldest month

a) Table Multivariate Tests for the one-way MANOVA

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Minimum Temperature Coldest Month	Pillai's Trace	.358	2.882	10.000	132.000	.003	.179
	Wilks' Lambda	.661	2.987[b]	10.000	130.000	.002	.187
	Hotelling's Trace	.483	3.089	10.000	128.000	.001	.194
	Roy's Largest Root	.410	5.417[c]	5.000	66.000	.000	.291

b) Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Minimum Temperature coldest month	Asc_Prevalence	207.836	2	103.918	1.868	.162	.051
	HW Prevalence	1468.861	2	734.430	3.502	.036	.092
	TT Prevalence	.940	2	.470	1.341	.268	.037
	SH_Prevalence	3955.374	2	1977.687	6.843	.002	.166
	SM_Prevalence	33.714	2	16.857	.590	.557	.017
Error	Asc Prevalence	3838.673	69	55.633			
	HW Prevalence	14471.136	69	209.727			
	TT Prevalence	24.190	69	.351			
	SH_Prevalence	19941.329	69	289.005			
	SM_Prevalence	1971.652	69	28.575			

a. R Squared = .224 (Adjusted R Squared = .201)

b. R Squared = .094 (Adjusted R Squared = .068)

c. R Squared = .145 (Adjusted R Squared = .121)

d. R Squared = .123 (Adjusted R Squared = .098)

4.5.7.3 **Maximum temperature hottest month**

The descriptive statistics in Table 4-15 provides the mean and standard deviation for the five dependent variables split by the four variable categories for maximum temperature hottest month. The highest mean prevalence (29.2 %, Std Dev. 13.649) was seen under good temperature for hookworm (Table 4-15). There was no statistical significant difference in prevalence of the SCH and STH species based on the maximum temperature hottest month $F(15,177)=1.406$, $p<0.148$; Wilk's $\Lambda=0.733$, partial eta squared $\eta^2=.098$ (Table 4-16a). The univariate ANOVAs test performed to determine how prevalence of SCH and STH species differ for the

annual mean temperature was also statistically insignificant on all the species including the mean scores with p>0.05 shown in Table 4-17. One-way MANOVA was statistically insignificant p=0.148 and therefore can conclude that prevalence of *Schistosoma* and soil transmitted helminths species were significantly independent on maximum temperature hottest month. In this case we accept the null hypothesis that maximum temperature hottest month has no effect on the prevalence of *Schistosoma* and soil transmitted helminths.

Table 4-15 Descriptive statistics for SCH and STH prevalence split by categories of maximum temperature hottest month

Maximum Temperature hottest month	Haematobium Mean; Std Dev	Mansoni Mean; Std Dev	Hookworm Mean; Std Dev	Ascaris Mean; Std Dev	Trichuris Mean; Std Dev
Cold	12.19;14.893	3.604;4.469	18.1;13.704	2.45;3.861	0.249;0.474
Good	8.61;7.195	3.27;4.159	29.2;13.649	0.77;0.582	0.333;0.074
Hot	3.41;1.060	0.33;0.471	0.33;0235	1.75;0.589	0.00;0.000
Very cold	18.69;22.312	2.49;6.380	15.7;15.858	6.67;10.159	0.403;0.739
Total	14.5;18.346	2.99;5.31	17.3;14.98	4.2;7.549	0.29; 0.594

Table 4-16 Multivariate Tests for the one-way MANOVA and Post Hoc Tests for SCH and STH species and the independent variable - maximum temperature hottest month

a) Table Multivariate Tests for the one-way MANOVA

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Maximum temperature hottest month	Pillai's Trace	.286	1.392	15.000	198.000	.154	.095
	Wilks' Lambda	.733	1.406	15.000	177.077	.148	.098
	Hotelling's Trace	.339	1.415	15.000	188.000	.144	.101
	Roy's Largest Root	.238	3.147 [c]	5.000	66.000	.013	.193

b) **Tests of Between-Subjects Effects**

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
maximum temperature hottest month	Asc_Prevalence	367.888	3	122.629	2.267	.089	.091
	HW Prevalence	1388.297	3	462.766	2.163	.100	.087
	TT Prevalence	.961	3	.320	.901	.445	.038
	SH_Prevalence	1155.977	3	385.326	1.152	.334	.048
	SM_Prevalence	34.693	3	11.564	.399	.754	.017
Error	Asc Prevalence	3678.621	68	54.097			
	HW Prevalence	14551.699	68	213.996			
	TT Prevalence	24.169	68	.355			
	SH_Prevalence	22740.726	68	334.422			
	SM_Prevalence	1968.354	69	28.527			

a. R Squared = .224 (Adjusted R Squared = .201)

b. R Squared = .094 (Adjusted R Squared = .068)

c. R Squared = .145 (Adjusted R Squared = .121) d. R Squared = .123 (Adjusted R Squared = .098)

Table 4-17 Summary of Multiple comparisons with Tukey's HSD post-hoc tests

Maximum Temperature Hottest month- Mean Score						
Category	Cold & good P-value	Cold & hot P-value	Cold & very cold p-value	Good & Hot p-value	Good & very cold p-value	Hot & very cold p-value
A. Lumbricoides	0.964	0.999	0.105	0.999	0.348	0.795
Hookworm	0.396	0.347	0.912	0.095	0.230	0.476
T. trichuris	0.875	0.940	0.725	1.000	0.572	0.790
S. haemtobium	0.977	0.912	0.484	0.986	0.662	0.662
S. mansoni	0.999	0.838	0.841	0.914	0.991	0.945

4.5.7.4 **Annual precipitation**

Table 4-18 shows the mean and standard deviation for prevalence data split according to the categories of the annual precipitation. The highest mean prevalence (28.52 %, Std Dev. 13.649) was seen under large storm for hookworm. There was a statistically significant difference in prevalence of the SCH and STH species based on annual precipitation $F(5, 66)=4.101^{b}$, p=0.003; Wilk's $\Lambda=0.763$, partial eta squared $\eta^2=.237$ in Table 4-19a. The univariate ANOVAs test performed to determine how prevalence of SCH and STH species differ for the annual precipitation revealed a statistically

significant effect only on hookworm, ($F(1, 70)=1622.116$, p=0.006; $\eta^2=.102$) as indicated in Table 4-19b. One-way MANOVA was statistically significant p=0.003 and therefore can conclude that prevalence of *Schistosoma* and soil transmitted helminths species were significantly dependent on annual precipitate. In this case we reject the null hypothesis that annual precipitate has no effect on the prevalence of *Schistosoma* and soil transmitted helminths.

Table 4-18 Descriptive statistics for SCH and STH prevalence split by categories of annual precipitation

Annual Precipitate	Haematobium Mean; Std Dev	Mansoni Mean; Std Dev	Hookworm Mean; Std Dev	Ascaris Mean; Std Dev	Trichuris Mean; Std Dev
Extreme storm	16.26;19.344	2.66;5.401	15.32;13.880	4.82;8.040	0.34;0.635
Large storm	5.34;5.771	4.85;4.587	28.52;15.606	0.66;0.746	0.04;0.109
Total	14.59;18.345	2.99;5.31	17.34;14.983	4.2;7.549	0.29;0.594

Table 4-19 Multivariate Tests for the one-way MANOVA and Post Hoc Tests for SCH and STH species and the independent variable - annual precipitate

a) Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Annual precipitation	Pillai's Trace	.237	4.101[b]	5.000	66.000	.003
	Wilks' Lambda	.763	4.101[b]	5.000	66.000	.003
	Hotelling's Trace	.311	4.101[b]	5.000	66.000	.003
	Roy's Largest Root	.311	4.101[b]	5.000	66.000	.003

b) Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Annual Precipitation	Asc_Prevalence	161.555	1	161.555	2.911	.092
	HWPrevalence	1622.116	1	1622.116	7.931	.006
	TT Prevalence	.802	1	.802	2.309	.133
	SM_Prevalence	44.641	1	44.641	1.594	.211
	SH_Prevalence	1110.367	1	1110.367	3.411	.069
Error	Asc_Prevalence	3884.954	70	55.499		

4.5.7.5 **Precipitation wettest month**

The descriptive statistics in Table 4-20 provides the mean and standard deviation for the five dependent variables split by the three variable categories for precipitation wettest month. The highest mean prevalence, 29.4 % was seen under no precipitation for hookworm and 21.12 % for *S. haematobium* under large storm. The multivariant tests indicate a statistically significant difference in prevalence of the SCH and STH species on precipitation wettest month $F(20, 209)=2.745$, p=0.000; Wilk's $\Lambda=0.463$, partial eta squared $\eta^2=.175$. The univariate ANOVAs test performed to determine how prevalence of SCH and STH species differ for precipitation wettest month revealed a statistically significant effect on *A. lumbricoides*, ($F(4, 67)=3.823$, p=0.007; $\eta^2=.186$), *T. trichuris* ($F(4, 67)=2.156$, p=0.010; $\eta^2=.177$), and *S. haematobium* ($F(4, 67)=2.654$, p=0.040; $\eta^2=.137$). However, further analysis to determine the difference between categories under the variable precipitate wettest month did not produce results. One-way MANOVA was statistically significant $p<0.0005$ and therefore can conclude that prevalence of *Schistosoma* and soil transmitted helminths species were significantly dependent on precipitation wettest month. In this case we reject the null hypothesis that precipitation wettest month has no effect on the prevalence of *Schistosoma* and soil transmitted helminths.

Table 4-20 Descriptive statistics for SCH and STH prevalence split by categories of precipitation wettest month

Precipitation wettest month	Haematobium Mean; Std Dev	Mansoni Mean; Std Dev	Hookworm Mean; Std Dev	Ascaris Mean; Std Dev	Trichuris Mean; Std Dev
Extreme storm	9.96;12.832	4.50;4.538	16.70;14.339	8.55;11.052	0.63;0.844
Large storm	21.12;22.042	3.16;6.220	14.34;13.873	2.27;3.243	0.13;0.317
none	4.07;4.175	1.69;3.077	29.53;17.138	0.71;0.766	0.05;0.115
Small	3.50;		18.33;	0.833;	0.16;
Total	14.5;18.346	2.99;5.31	17.34;14.983	4.2;7.549	0.29;0.594

Table 4-21 Multivariate Tests for the one-way MANOVA and Post Hoc Tests for SCH and STH species and the independent variable -precipitation driest month

a) Table Multivariate Tests for the one-way MANOVA

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Precipitation wettest month	Pillai's Trace	.642	2.526	20.000	264.000	.000	.161
	Wilks' Lambda	.463	2.745	20.000	209.897	.000	.175
	Hotelling's Trace	.939	2.888	20.000	246.000	.000	.190
	Roy's Largest Root	.581	7.675[c]	5.000	66.000	.000	.368

b) **Tests of Between-Subjects Effects**

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Precipitate wettest Month	Asc_Prevalence	751.914	4	187.979	3.823	.007	.186
	HW prevalence	1817.829	4	454.457	2.156	.083	.114
	TT Prevalence	4.444	4	1.111	3.598	.010	.177
	SM_Prevalence	3268.041	4	817.010	2.654	.040	.137
	SH_Prevalence	242.314	4	60.579	2.302	.068	.121
Error	Asc_Prevalence	3294.595	67	49.173			
	HW Prevalence	14122.168	67	210.779			
	TT Prevalence	20.686	67	.309			
	SM_Prevalence	1944.731	69	28.185			
	SH_Prevalence	22503.283	69	326.135			

4.5.7.6 **Precipitation driest month**

The descriptive statistics in Table 4-22 provides the mean and standard deviation for the five dependent variables split by the three variable categories for precipitation driest month. The highest mean prevalence (27.4 %; Std Dev. 16.296) was seen under heavy precipitation for hookworm. The multivariant tests indicate a statistically significant difference in prevalence of the SCH and STH species on precipitation driest month $F(10, 130)=2.796^{b}$, p=0.004; Wilk's $\Lambda=0.677$, partial eta squared $\eta^2=.177$ (Table 4-23a). The univariate ANOVAs test (Table 4-23b) performed to determine how prevalence of SCH and STH species differ for precipitation driest month revealed a statistically significant effect only on hookworm, ($F(2, 69)=3.932$,

p=0.024; η^2=.102). Further only the mean score between heavy and small precipitate was statistically significant (p=0.021) for hookworm. The rest of the mean scores were not statistically significant including those for the other four species. One-way MANOVA was statistically significant p=0.004 and therefore can conclude that prevalence of *Schistosoma* and soil transmitted helminths species were significantly dependent on precipitation driest month specifically for hookworm. In this case we reject the null hypothesis that precipitation driest month has no effect on the prevalence of *Schistosoma* and soil transmitted helminths.

Table 4-22 Descriptive statistics for SCH and STH prevalence split by categories of precipitation driest month

Precipitation driest month	Haematobium Mean; Std Dev	Mansoni Mean; Std Dev	Hookworm Mean; Std Dev	Ascaris Mean; Std Dev	Trichuris Mean; Std Dev
Heavy (25-50)	5.19;5.528	4.50;4.538	27.40;16.296	0.68;0.713	0.57;0.110
None (0)	17.43;20.759	3.16;6.220	16.48;15.954	5.73;9.374	0.42;.0723
Small (<10)	14.39;16.547	1.69;3.077	12.84;8.185	3.07;3.77	0.16;0.360
Total	14.5;18.346	2.99;5.31	17.34;14.983	4.2;7.549	0.29;0.594

Table 4-23 Multivariate Tests for the one-way MANOVA and Post Hoc Tests for SCH and STH species and the independent variable – precipitation driest month

a) Table Multivariate Tests for the one-way MANOVA

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Precipitation driest month	Pillai's Trace	.343	2.736	10.000	132.000	.004	.172
	Wilks' Lambda	.677	2.796[b]	10.000	130.000	.004	.177
	Hotelling's Trace	.446	2.854	10.000	128.000	.003	.182
	Roy's Largest Root	.362	4.776[c]	5.000	66.000	.001	.266

b) Univariate ANOVA test for precipitation driest month on SCH and STH Prevalence

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Precipitate Driest Month	Asc_Prevalence	270.283	2	135.142	2.469	.092	.067
	HW prevalence	1630.809	2	815.405	3.932	.024	.102
	TT Prevalence	1.711	2	.855	2.520	.088	.068
	SM_Prevalence	60.635	2	30.318	1.076	.347	.030
	SH_Prevalence	1393.420	2	696.710	2.136	.126	.058
Error	Asc_Prevalence	3776.225	69	54.728			
	HW Prevalence	14309.187	69	207.380			
	TT Prevalence	23.419	69	.339			
	SM_Prevalence	1944.731	69	28.185			
	SH_Prevalence	22503.283	69	326.135			

Table 4-24 Summary of Multiple comparisons with Tukey's HSD post-hoc tests

Precipitation driest month- Mean Score			
Category	Heavy-none P-value	Heavy-small P-value	None-small p-value
A. Lumbricoides	0.101	0.657	0.400
Hookworm	0.061	0.021	0.635
T. trichuris	0.138	0.872	0.244
S. haemtobium	0.104	0.356	0.816
S. mansoni	0.723	0.329	0.581

4.5.7.7 **Clay topsoil**

The descriptive statistics in Table 4-25 provides the mean and standard deviation for the five dependent variables split by the three variable categories for clay topsoil. The highest mean prevalence (39.02 %; SD 10.139) was seen under standard depth 5 (60-100 cm) for hookworm. The multivariant tests indicate a statistically significant difference in prevalence of the SCH and STH species on clay topsoil $F(10, 130)=4.034^{b}$, $p<0.0005$; Wilk's $\Lambda=0.582$, partial eta squared $\eta^2=.237$ (table 4-26a). The univariate ANOVAs test performed to determine how prevalence of SCH and STH species differ for clay topsoil revealed a statistically significant effect on hookworm, ($F(2, 69)=6.256$, $p=0.003$; $\eta^2=.159$), *T. trichuris* ($F(2, 69)=4.966$, $p=0.010$; $\eta^2=.126$), *S. haematobium* ($F(2, 69)=5.383$, $p=0.007$; $\eta^2=.135$) and *S. mansoni* ($F(2, 69)=3.504$, $p=0.036$; $\eta^2=.102$) but was not statistically significant for

A. lumbricoides (Table 4-26b). However, further analysis to determine the difference between the different categories under the variable clay topsoil for each species using Turkey HSD test, the mean scores for hookworm were statistically different for Sd3 & Sd5 and Sd4 & Sd5, (p=0.002, and p=0.004), for *T. trichuris* Sd3 & Sd4 (p=0.009) and *S. haematobium* Sd3 & Sd4 (p=0.013) and none of the scores for *A. lumbricoides* were statistically significant as indicated in Table 4-27. One-way MANOVA was statistically significant p<0.0005 and therefore can conclude that prevalence of *Schistosoma* and soil transmitted helminths species were significantly dependent on clay topsoil. In this case we reject the null hypothesis that clay topsoil has no effect on the prevalence of *Schistosoma* and soil transmitted helminths.

Table 4-25 Descriptive statistics for SCH and STH prevalence split by categories of clay topsoil

Clay topsoil (standard depth -Sd)	Haematobium Mean; Std Dev	Mansoni Mean; Std Dev	Hookworm Mean; Std Dev	Ascaris Mean; Std Dev	Trichuris Mean; Std Dev
Sd3	20.04;20.619	3.63;6.192	15.43;13.049	3.24;5.256	0.15;0.313
Sd4	7.15;10.818	1.05;2.547	16.25;15.936	6.69;10.676	0.59;0.876
Sd5	3.45;5.542	6.91;3.890	39.02;10.139	0.32;0.348	0.10;0.151
Total	14.5;18.346	2.99;5.31	17.34;14.983	4.2;7.549	0.29;0.594

Table 4-26 Multivariate Tests for the one-way MANOVA and Post Hoc Tests for SCH and STH species and the independent variable – clay topsoil

a) Table Multivariate Tests for the one-way MANOVA

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Clay topsoil	Pillai's Trace	.473	4.092	10.000	132.000	.000	.237
	Wilks' Lambda	.582	4.034[b]	10.000	130.000	.000	.237
	Hotelling's Trace	.621	3.975	10.000	128.000	.000	.237
	Roy's Largest Root	.337	4.452[c]	5.000	66.000	.001	.252

b) Univariate ANOVA test for precipitation driest month on SCH and STH Prevalence

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Clay topsoil	Asc_Prevalence	263.732	2	131.866	2.405	.098	.065
	HW prevalence	2535.469	2	1267.735	6.526	.003	.159
	TT Prevalence	3.162	2	1.581	4.966	.010	.126
	SM_Prevalence	3225.448	2	1612.724	5.383	.007	.135
	SH_Prevalence	184.902	2	92.451	3.504	.036	.092
Error	Asc_Prevalence	3782.776	69	54.823			
	HW Prevalence	13404.527	69	194.269			
	TT Prevalence	21.968	69	.318			
	SM_Prevalence	20671.255	69	299.583			
	SH_Prevalence	1820.465	69	26.384			

Table 4-27 Summary of Multiple comparisons with Tukey's HSD post-hoc tests

Standard depth clay topsoil - Mean Score			
Category	Sd3 & Sd4 P-value	Sd3 & Sd5 P-value	Sd4 & Sd5 p-value
A. Lumbricoides	0.168	0.683	0.194
Hookworm	0.971	0.002	0.004
T. trichuris	0.009	0.981	0.191
S. haemtobium	0.013	0.113	0.902
S. mansoni	0.127	0.371	0.059

4.5.7.8 **Power of hydrogen (pH) topsoil**

The descriptive statistics in Table 4-28 provides the mean and standard deviation for the five dependent variables split by the three (acidic, neutral and strongly acidic) variable categories for pH topsoil. The highest mean prevalence (36.4 %; Std Dev 8.480 and 16.06 %; Std Dev 14.209) was seen under Neutral and acidic pH conditions for hookworm, respectively. The multivariant tests indicate a statistically significant difference in prevalence of the SCH and STH species on pH topsoil $F(10, 132)=2.707^{b}$, p=0.005; Wilk's Λ=0.685, partial eta squared $\eta^2=.172$ (Table 4-29a). The univariate ANOVAs test performed to determine how prevalence of SCH and STH species differ for pH topsoil revealed a statistically significant effect on hookworm, ($F(2, 69)=4.836$, p=0.011; $\eta^2=.123$), *A. lumbricoides* ($F(2, 69)=4.030$,

p=0.022; η^2=.105) and *S. mansoni* ($F(2, 69)=3.695$, p=0.030; η^2=.097) as indicated in Table 4-29b. Further, multiple comparison to assess the difference between different categories under pH topsoil for each species on the observed means using Turkey HSD test showed statistically significant mean difference (acidic & neutral p=0.009 and strongly acidic & neutral p=0.015) for hookworm, (neutral & strongly acidic p=0.030,) for *S. mansoni* and (neutral-acidic & strongly p=0.036) for *A. lumbricoides* as shown in Table 4-30. The rest of the mean scores were not statistically significant including those for the other species. One-way MANOVA was statistically significant p=0.005 and therefore can conclude that prevalence of *Schistosoma* and soil transmitted helminths species were significantly dependent on pH topsoil. In this case we reject the null hypothesis that pH topsoil has no effect on the prevalence of *Schistosoma* and soil transmitted helminths.

Table 4-28 Descriptive statistics for SCH and STH prevalence split by categories of pH topsoil

PH topsoil	Haematobium Mean; Std Dev	Mansoni Mean; Std Dev	Hookworm Mean; Std Dev	Ascaris Mean; Std Dev	Trichuris Mean; Std Dev
Acidic	16.46;19.802	3.29;5.831	16.06;14.209	3.38;5.776	0.23;0.516
Neutral	2.47;2.566	7.40;4.264	36.41;8.480	0.15;0.219	0.10;0.151
Strongly acidic	12.14;14.304	0.51;0.550	15.40;15.572	8.66;11.714	0.57;0.838
Total	14.5;18.346	2.99;5.31	17.34;14.983	4.2;7.549	0.29;0.594

Table 4-29 Multivariate Tests for the one-way MANOVA and Post Hoc Tests for SCH and STH species and the independent variable – pH topsoil

a) Table Multivariate Tests for the one-way MANOVA

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
PH topsoil	Pillai's Trace	.341	2.716	10.000	132.000	.005	.171
	Wilks' Lambda	.685	2.707[b]	10.000	130.000	.005	.172
	Hotelling's Trace	.421	2.698	10.000	128.000	.005	.174
	Roy's Largest Root	.289	3.812[c]	5.000	66.000	.004	.224

b) Univariate ANOVA test for pH topsoil on SCH and STH Prevalence

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
pH topsoil	Asc_Prevalence	423.242	2	211.621	4.030	.022	.105
	HW prevalence	1959.512	2	979.756	4.836	.011	.123
	TT Prevalence	1.565	2	.783	2.291	.109	.062
	SM_Prevalence	1005.609	2	502.804	1.516	.227	.042
	SH_Prevalence	193.995	2	96.998	3.695	.030	.097
Error	Asc_Prevalence	3623.267	69	52.511			
	HW Prevalence	13980.484	69	202.616			
	TT Prevalence	23.565	69	.342			
	SM_Prevalence	22891.094	69	331.755			
	SH_Prevalence	1811.371	69	26.252			

Table 4-30 Summary of Multiple comparisons with Tukey's HSD post-hoc tests

PH topsoil - Mean Score			
Category	Acidic-neutral P-value	Acidic-strongly acidic P-value	Neutral-strongly acidic p-value
A. Lumbricoides	0.628	0.036	0.067
Hookworm	0.009	0.986	0.015
T. trichuris	0.884	0.120	0.268
S. haemtobium	0.236	0.699	0.562
S. mansoni	0.207	0.161	0.030

4.5.7.9 **Sand topsoil**

The descriptive statistics in Table 4-31 provides the mean and standard deviation for the five dependent variables split by the four variable categories for sand topsoil. The highest mean prevalence (31,85 % SD 12.579 and 24.22 % SD 18.790) was seen under Sd2 and Sd3 for hookworm. The multivariant tests indicate a statistically significant difference in prevalence of the SCH and STH species on sand topsoil $F(15, 177)=1.855$, $p=0.031$; Wilk's $\Lambda=0.668$, partial eta squared $\eta^2=.126$ (Table 4-32a). The univariate ANOVAs tests of between subject effects on prevalence of SCH and STH species differ for sand topsoil did not reveal any statistically significant effect on the prevalence of any species and therefore no multiple comparison between

different categories. One-way MANOVA was statistically significant p<0.0005 and therefore can conclude that prevalence of *Schistosoma* and soil transmitted helminths species were significantly dependent on sand topsoil. In this case we reject the null hypothesis that sand topsoil has no effect on the prevalence of *Schistosoma* and soil transmitted helminths.

Table 4-31 Descriptive statistics for SCH and STH prevalence split by categories of sand top soil

Sand topsoil	Haematobium Mean; Std Dev	Mansoni Mean; Std Dev	Hookworm Mean; Std Dev	Ascaris Mean; Std Dev	Trichuris Mean; Std Dev
Sd2	1.81;1.245	5.34;4.586	31.85;12.579	0.32;0.348	0.13;0.140
Sd3	7.60;6.220	3.90;4.767	24.22;18.790	0.93;0.820	0.0;0.0
Sd4	16.11;21.278	2.40;4.864	15.07;14.035	5.94;9.052	0.43;0.703
Sd5	17.54;12.937	3.57;7.018	16.10;14.344	1.74;2.064	0.08;0.273
Total	14.5;18.346	2.99;5.31	17.34;14.983	4.2;7.549	0.29;0.594

Table 4-32Multivariate Tests for the one-way MANOVA and Post Hoc Tests for SCH and STH species and the independent variable – sand topsoil

a) Table Multivariate Tests for the one-way MANOVA

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Sand topsoil standard depth	Pillai's Trace	.351	1.747	15.000	198.000	.045	.117
	Wilks' Lambda	.668	1.855	15.000	177.077	.031	.126
	Hotelling's Trace	.468	1.954	15.000	188.000	.021	.135
	Roy's Largest Root	.397	5.246[c]	5.000	66.000	.000	.284

b) Univariate ANOVA test for precipitation driest month on SCH and STH Prevalence

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Sand topsoil (standard depth)	Asc_Prevalence	376.737	3	125.579	2.327	.082	.093
	HW prevalence	1640.522	3	546.841	2.600	.059	.103
	TT Prevalence	2.246	3	.749	2.224	.093	.089
	SM_Prevalence	1393.681	3	464.560	1.404	.249	.058
	SH_Prevalence	54.040	3	18.013	.628	.600	.027
Error	Asc_Prevalence	3669.772	68	53.967			
	HW Prevalence	14299.474	68	210.286			
	TT Prevalence	22.884	68	.337			
	SM_Prevalence	22503.022	68	330.927			
	SH_Prevalence	1951.327	68	28.696			

Table 4-33 Summary of Multiple comparisons with Tukey's HSD post-hoc tests

Sand topsoil - Mean Score						
Category	Sd2 Sd3 P-value	Sd2-Sd4 P-value	Sd2-Sd5 p-value	Sd3-Sd4 p-value	Sd3-Sd5 p-value	Sd4-Sd5 p-value
A. Lumbricoides	0.999	0.373	0.982	0.342	0.995	0.231
Hookworm	0.806	0.076	0.162	0.411	0.614	0.995
T. trichuris	0.978	0.706	0.998	0.270	0.990	0.191
S. haemtobium	0.948	0.349	0.345	0.659	0.633	0.994
S. mansoni	0.968	0.652	0.919	0.901	0.999	0.884

4.5.7.10 **Silt topsoil**

The descriptive statistics in Table 4-34 provides the mean and standard deviation for the five dependent variables split by the four variable categories for silt topsoil. The highest mean prevalence (27.40 % SD 16.296 and 17.60 % SD 15.659) was seen under Sd6 and Sd2 for hookworm and 1718 %, Std Dev 21.968 Sd3 for *S. heamtobium*. The multivariant tests indicate a statistically significant difference in prevalence of the SCH and STH species on silt topsoil $F(10, 132)=3.801$, $p<0.0005$; Wilk's $\Lambda=0.599$, partial eta squared $\eta^2=.226$ Table 4-35a. The univariate ANOVAs test performed to determine how prevalence of SCH and STH species differ for silt topsoil revealed a statistically significant effect on *A. lumbricoides*, ($F(2, 69)=4.671$,

p=0.013; η^2=.119), and hookworm (F(2, 69)=3.799, p=0.027; η^2=.099) in Table 4-35b. Further, multiple comparison to assess the difference between different categories under silt topsoil for each species on the observed means using Turkey HSD test showed statistically significant mean difference between Sd2 & Sd3 (p=0.046), and Sd3 & Sd6 (p=0.049) for *A. lumbricoides*, Sd3 & Sd6 (p=0.020,) for hookworm as indicated in Table 4-36. The rest of the mean scores were not statistically significant including those for the other species. One-way MANOVA was statistically significant p<0.0005 and therefore can conclude that prevalence of soil transmitted helminths species is significantly dependent on silt topsoil. In this case we reject the null hypothesis that silt topsoil has no effect on the prevalence of soil transmitted helminths.

Table 4-34 Descriptive statistics for SCH and STH prevalence split by categories of annual mean temperature

Silt topsoil	Haematobium Mean; Std Dev	Mansoni Mean; Std Dev	Hookworm Mean; Std Dev	Ascaris Mean; Std Dev	Trichuris Mean; Std Dev
Sd2	14.66;11.013	1.70;3.613	17.60;15.659	1.30;1.196	0.13;0.300
Sd3	17.18;21.968	3.09;6.003	14.43;13.375	6.31;9.174	0.42;0.719
Ss6	5.19;5.528	4.50;4.538	27.40;16.296	0.67;0.7130	0.05;0.110
Total	14.5;18.346	2.99;5.31	17.34;14.983	4.2;7.549	0.29;0.594

Table 4-35 Multivariate Tests for the one-way MANOVA and Post Hoc Tests for SCH and STH species and the independent variable – Silt topsoil

a) Table Multivariate Tests for the one-way MANOVA

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Silt topsoil	Pillai's Trace	.424	3.555	10.000	132.000	.000	.212
	Wilks' Lambda	.599	3.801[b]	10.000	130.000	.000	.226
	Hotelling's Trace	.632	4.043	10.000	128.000	.000	.240
	Roy's Largest Root	.563	7.436[c]	5.000	66.000	.000	.360

b) Univariate ANOVA test for precipitation driest month on SCH and STH Prevalence

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Silt topsoil	Asc_Prevalence	482.500	2	241.250	4.671	.013	.119
	HW prevalence	1581.109	2	790.555	3.799	.027	.099
	TT Prevalence	1.834	2	.917	2.717	.073	.073
	SM_Prevalence	1350.507	2	675.253	2.067	.134	.057
	SH_Prevalence	56.238	2	28.119	.995	.375	.028
Error	Asc_Prevalence	3564.009	69	51.652			
	HW Prevalence	14358.887	69	208.100			
	TT Prevalence	23.295	69	.338			
	SM_Prevalence	22546.196	69	326.756			
	SH_Prevalence	1949.128	69	28.248			

Table 4-36 Summary of Multiple comparisons with Tukey's HSD post-hoc tests

Silt topsoil- Mean Score			
Category	Sd2 & Sd3 P-value	Sd2 & Sd6 P-value	Sd3 & Sd6 p-value
A. Lumbricoides	0.046	0.971	0.049
Hookworm	0.724	0.176	0.020
T. trichuris	0.200	0.930	0.135
S. haemtobium	0.877	0.352	0.112
S. mansoni	0.633	0.347	0.696

4.5.7.11 **Elevation (SRMT)**

The descriptive statistics in Table 4-37 provides the mean and standard deviation for the five dependent variables split by the four variable categories for elevation. The was seen under for *S. heamtobium* and 17.02 %, Std Dev 15.050 Sd3 for hookworm. The multivariant tests in Table 4-37a indicate a statistically significant difference in prevalence of the SCH and STH species on elevation $F(5, 54)=2.824$, p=0.025 Wilk's $\Lambda=0.793$, partial eta squared $\eta^2=.207$. The univariate ANOVAs test performed to determine how prevalence of SCH and STH species differ for elevation was statistically insignificant as shown in Table 4-37b. One-way MANOVA was statistically significant p=0.025 and therefore can conclude that prevalence of *Schistosoma* and soil transmitted helminths species were significantly dependent on

elevation. In this case we reject the null hypothesis that elevation has no effect on the prevalence of *Schistosoma* and soil transmitted helminths.

Table 4-37 Descriptive statistics for SCH and STH prevalence split by categories of elevation

Elevation (SRTM 1km)	Haematobium Mean; Std Dev	Mansoni Mean; Std Dev	Hookworm Mean; Std Dev	Ascaris Mean; Std Dev	Trichuris Mean; Std Dev
<1000	25.54;24.881	4.78;5.587	8.54;4.516	3.35;4.565	0.01;0.048
≥1000	14.20;17.408	2.17;5.334	17.02;15.050	5.27;8.750	0.42;0.692
Total	16.47;19.435	2.69;5.440	15.33;13.997	4.2;7.549	0.34;0.640

Table 4-38
Multivariate Tests for the one-way MANOVA and Post Hoc Tests for SCH and STH species and the independent variable - elevation

a) Table Multivariate Tests for the one-way MANOVA

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Elevation	Pillai's Trace	.207	2.824[b]	5.000	54.000	.025	.207
	Wilks' Lambda	.793	2.824[b]	5.000	54.000	.025	.207
	Hotelling's Trace	.261	2.824[b]	5.000	54.000	.025	.207
	Roy's Largest Root	.261	2.824[b]	5.000	54.000	.025	.207

b) Univariate ANOVA test for precipitation driest month on SCH and STH Prevalence

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Elevation	Asc_Prevalence	35.385	1	35.385	.536	.467	.009
	HW prevalence	690.083	1	690.083	3.682	.060	.060
	TT Prevalence	1.629	1	1.629	4.192	.045	.067
	SM_Prevalence	65.527	1	65.527	2.261	.138	.038
	SH_Prevalence	1234.247	1	1234.247	3.400	.070	.055
Error	Asc_Prevalence	3827.787	58	65.996			
	HW Prevalence	10870.049	58	187.415			
	TT Prevalence	22.546	58	.389			
	SM_Prevalence	1680.669	58	28.977			
	SH_Prevalence	21053.475	58	362.991			

4.5.8 Actionable insight to guide schistosomiasis and soil transmitted helminthiasis programmatic roadmap

4.5.8.1 Population at risk

Based on the Central Statistics census data projections for 2019 (Zambia Central statistics, 2012), and the prevalence data from the study, the overall population at risk for schistosomiasis stands at 31.9% (n=4.97M) in Table 4-15. The study findings indicate 14.5% of the population live in at high risk areas of Schistosoma infection, 65.8% in moderate risk areas and 19.6% in the low risk areas. Lusaka Province has the highest population at risk at 9.4% (n=1.5M) of the national population and contributes 29.3 % of the overall population at risk and the next province is Eastern at 4.4 % (n=0.7M) contributing 13.9 % of the national population. The lowest population at risk was recorded in Northern at 1.6 % (n=0.23M), followed by Western at 1.6% (n=0.25M). At district level the highest population at risk was Lusaka at 18.4 % followed by Kafue at 5.7 % and Chongwe at 4.7 % while the lowest population at risk was recorded in Itezi-tezi which contributes only 0.25 % of the population at risk, followed by Mambwe and Chavuma districts contributing 0.27 % and 0.32 % population at risk, respectively.

The national overall STH population at risk of SAC and Pre-SAC is 17.6 % (n=2.74M) as shown in Table 4-16 5.8 % of the population live-in high-risk communities and are at risk of infection, 56.1 % live in low risk communities and 38.1% in very low to non-endemic areas. At the province, the highest population at risk was found in Western and Northwestern Provinces at 1.3 % (n=2.1M) each of the national population contributing 45.0 % of the overall population at high risk. The other provinces with a population at high risk are Luapula, Muchinga and Copperbelt. The population with very low or negligible risk was recorded in Southern at 11.3 % (n=1.8M) of the national population followed by Central at 6.4 %(n=1.0M). At district level the highest population at risk is in Lusaka at 14.4 % (n=2.2M).

4.5.8.2 Treatment strategy

Only 2.8% of the districts are non-endemic and do not require treatment with praziquantel. 43.1% of the districts have low risk and will require one round of treatment every three years or once at school entry in grade 1 and on exist in grade

7, 47.2% districts have moderate endemicity and will require biannual treatments and 6.9% highly endemic districts require yearly treatments as shown in Figures 4-54.

Using the upper 95% CI of STH prevalence, 36.1% of the districts were found to have thresholds below the level requiring mass drug administration and therefore no treatment with neither albendazole nor mebendazole will be administered. 52.8% of the districts require once yearly treatment and 11.1% require twice yearly treatment (6monthly treatments) in line with the WHO guidelines. The breakdown is shown in Figure 4-55.

Table 4-39 Population requiring treatment for schistosomiasis at the district level.

Province_Name	District_Name	District Population	Endemicity	Total Pop requiring treatment	Pre-SAC	SAC
Central	Chibombo	446706	Low	62582	10720	51862
Central	Itezhi-tezhi	87176	Low	12213	2092	10121
Central	Kabwe	221007	Low	36264	5304	30960
Central	Kapiri Mposhi	294971	Low	48404	7079	41325
Central	Mkushi	188071	Moderate	79995	7522	43914
Central	Mumbwa	273869	Low	44940	6572	38368
Central	Serenje	190392	Low	31242	4569	26673
Copperbelt	Chililabombwe	114282	Low	18752	2742	16010
Copperbelt	Chingola	259981	Low	42662	6239	36423
Copperbelt	Kalulushi	123359	Low	20242	2960	17282
Copperbelt	Kitwe	646827	Low	106143	15523	90620
Copperbelt	Luanshya	172170	Low	28251	4131	24120
Copperbelt	Lufwanyama	93622	Low	15362	2246	13116
Copperbelt	Masaiti	116244	Low	19074	2789	16285
Copperbelt	Mpongwe	119712	Low	19643	2872	16771
Copperbelt	Ndola	530129	None	0	0	0
Copperbelt	Mufulira	185844	Low	30496	4460	26036
Eastern	Chipata	508361	Moderate	208122	20334	118702
Eastern	Lundazi	378225	Moderate	151962	14075	82163
Eastern	Petauke	351876	Moderate	135864	11079	64677
Eastern	Katete	276991	Moderate	93343	3746	21869
Eastern	Nyimba	93659	Moderate	41384	4858	28359
Eastern	Chadiza	121456	Moderate	45502	3315	19351
Eastern	Mambwe	82877	Low	13599	1989	11610
Luapula	Chienge	133501	Moderate	54655	5340	31172
Luapula	Nchelenge	179352	Moderate	73426	7174	41878
Luapula	Milenge	54127	High	54127	4330	25277
Luapula	Mansa	257517	Moderate	105426	10300	60130
Luapula	Kawambwa	154294	Low	25336	3720	21616
Luapula	Samfya	170327	Moderate	69731	6813	39771
Luapula	Mwense	220327	Moderate	90201	8813	51446
Lusaka	Chongwe	230400	High	230400	18432	107596
Lusaka	Kafue	282998	High	282998	22639	132160
Lusaka	Luangwa	27954	High	27954	2236	13054
Lusaka	Lusaka	2236090	Moderate	915454	89443	522127
Muchinga	Nakonde	161472	Low	26497	3875	22622
Muchinga	Chama	131514	Moderate	53840	5260	30708
Muchinga	Isoka	175759	Moderate	71955	7030	41039
Muchinga	Mpika	257786	Moderate	105537	10311	60193
Muchinga	Chinsali	168527	Low	27654	4044	26610
Northern	Chilubi	90158	None	0	0	0
Northern	Kaputa	141053	Moderate	57746	5642	32935
Northern	Kasama	272238	Low	44674	6533	38140
Northern	Luwingu	151932	Low	24932	3646	21285
Northern	Mbala	238660	Low	39164	5727	33436
Northern	Mporokoso	115301	Low	18920	2767	16153
Northern	Mpulungu	118886	Low	19509	2853	16655
Northern	Mungwi	176207	Low	28915	4228	24686
North Western	Chavuma	38969	Moderate	15953	1558	9099
North Western	Kabompo	107732	Moderate	45605	4309	25155
North Western	Kasempa	82549	Moderate	33794	3301	19275
North Western	Mufumbwe	68337	Moderate	27976	2733	15956
North Western	Mwinilunga	117995	Moderate	48305	4719	27551
North Western	Solwezi	291876	Moderate	68153	11675	68153
North Western	Zambezi	126360	High	126360	10108	59010
Southern	Choma	276733	Moderate	113294	11069	64617
Southern	Gwembe	66781	Moderate	27339	2671	15593
Southern	Mazabuka	250275	Low	41070	6006	35063
Southern	Kalomo	321627	Moderate	131673	12865	75099
Southern	Kazungula	130790	Moderate	53544	5231	30539
Southern	Namwala	116337	Moderate	47627	4653	27164
Southern	Monze	211112	Low	34643	5066	29576
Southern	Siavonga	112606	Moderate	46100	4504	26293
Southern	Sinazongwe	115823	Moderate	47416	4632	27044
Southern	Livingstone	164157	Moderate	57205	6566	28330
Western	Kalabo	113043	Low	18550	2713	15837
Western	Kaoma	173316	Moderate	70054	6032	40469
Western	Lukulu	67192	Moderate	27507	2687	15689
Western	Mongu	191186	Low	31373	4588	26785
Western	Senanga	109582	Low	17982	2629	15352
Western	Sesheke	140903	Moderate	57685	5636	32900
Western	Shang'ombo	166278	Low	27286	3990	23295
National/Zambia	72	15585746		4971586	518313	3011150

In high-risk areas: total population of SAC and adults In moderate-risk areas: 1/2 of SAC population and 1/3 of adult population* In low-risk areas: 1/3 of SAC population *

Table 4-40 Population requiring treatment for soil transmitted helminthiasis at the district level

Province	District	Endemicity Status	District Population	Total Pop requiring treatment	Pre-SAC	SAC	WHO STH treatment based on Upper 95% Confidence Interval
Central	Chibombo	Low	446706	0	0	0	No treatment
Central	Itezhi-tezhi	Low	87176	0	0	0	No treatment
Central	Kabwe	Low	221007	0	0	0	No treatment
Central	Kapiri Mposhi	moderate	294971	48404	7079	41325	Tx SAC Once yearly
Central	Mkushi	moderate	188071	51436	7522	43914	Tx SAC Once yearly
Central	Mumbwa	Low	273869	0	0	0	No treatment
Central	Serenje	moderate	190392	31242	4569	26673	Tx SAC Once yearly
Copperbelt	Chililabombwe	Moderate	114282	18752	2742	16010	Tx SAC Once yearly
Copperbelt	Chingola	Low	259981	0	0	0	No treatment
Copperbelt	Kalulushi	Moderate	123359	20242	2960	17282	Tx SAC Once yearly
Copperbelt	Kitwe	Moderate	646827	106143	15523	90620	Tx SAC Once yearly
Copperbelt	Luanshya	Moderate	172170	28251	4131	24120	Tx SAC Once yearly
Copperbelt	Lufwanyama	Moderate	93622	15362	2246	13116	Tx SAC Once yearly
Copperbelt	Masaiti	Low	116244	19074	2789	16285	Tx SAC Once yearly
Copperbelt	Mpongwe	Moderate	119712	19643	2872	16771	Tx SAC Once yearly
Copperbelt	Mufulira	High	185844	30496	4460	26036	Tx SAC Once yearly
Copperbelt	Ndola	Low	530129	0	0	0	No treatment
Eastern	Chadiza	moderate	121456	68916	20334	48582	Tx SAC Once yearly
Eastern	Chipata	Low	508361	0	0	0	No treatment
Eastern	Katete	Low	276991	0	0	0	No treatment
Eastern	Lundazi	moderate	378225	25615	3746	21869	Tx SAC Once yearly
Eastern	Mambwe	Low	82877	0	0	0	Tx SAC Once yearly
Eastern	Nyimba	moderate	93659	22666	3315	19351	Tx SAC Once yearly
Eastern	Petauke	Moderate	351876	13599	1989	11610	Tx SAC Once yearly
Luapula	Chiengi	moderate	133501	36512	5340	31172	Tx SAC Once yearly
Luapula	Kawambwa	Low	154294	0	0	0	No treatment
Luapula	Mansa	Low	257517	0	0	0	No treatment
Luapula	Milengi	High	54127	27079	10300	16779	Tx SAC Twice Yearly
Luapula	Mwense	Low	220327	0	0	0	No treatment
Luapula	Nchelenge	Low	179352	46584	6813	39771	Tx SAC Once yearly
Luapula	Samfya	Low	170327	0	0	0	No treatment
Lusaka	Chongwe	Low	230400	0	0	0	No treatment
Lusaka	Kafue	moderate	282998	154799	22639	132160	Tx SAC Once yearly
Lusaka	Luangwa	Moderate	27954	27954	2236	13054	Tx SAC Once yearly
Lusaka	Lusaka	Moderat e	2236090	915454	89443	522127	Tx SAC Once yearly
Muchinga	Chama	moderate	131514	26497	3875	22622	Tx SAC Once yearly
Muchinga	Chinsali	High	168527	53840	5260	30708	Tx SAC Twice Yearly
Muchinga	Isoka	Low	175759	0	0	0	No treatment
Muchinga	Mpika	Moderate	257786	70504	10311	60193	Tx SAC Once yearly

Muchinga	Nakonde	Moderate	161472	27654	4044	26610	Tx SAC Once yearly
Northern	Chilubi	High	90158	44906	17859	27047	Tx SAC Twice Yearly
Northern	Kaputa	Moderate	141053	57746	5642	32935	Tx SAC Once yearly
Northern	Kasama	Moderate	272238	44674	6533	38140	Tx SAC Once yearly
Northern	Luwingu	Moderate	151932	24931	3646	21285	Tx SAC Once yearly
Northern	Mbala	Low	238660	0	0	0	No treatment
Northern	Mporokoso	Low	115301	0	0	0	No treatment
Northern	Mpulungu	Moderate	118886	19509	2853	16655	Tx SAC Once yearly
Northern	Mungwi	Moderate	176207	28915	4228	24686	Tx SAC Once yearly
North Western	Chavuma	Moderate	38969	15953	1558	9099	Tx SAC Once yearly
North Western	Kabompo	Moderate	107732	45605	4309	25155	Tx SAC Once yearly
North Western	Kasempa	High	82549	33794	3301	19275	Tx SAC Twice Yearly
North Western	Mufumbwe	Moderate	68337	27976	2733	15956	Tx SAC Once yearly
North Western	Mwinilunga	High	117995	48305	4719	27551	Tx SAC Twice Yearly
North Western	Solwezi	Moderate	291876	68153	11675	68153	Tx SAC Once yearly
North Western	Zambezi	Moderate	126360	126360	10108	59010	Tx SAC Once yearly
Southern	Choma	Low	276733	0	0	0	No treatment
Southern	Gwembe	Low	66781	0	0	0	No treatment
Southern	Kalomo	Low	321627	0	0	0	No treatment
Southern	Kazungula	Low	130790	0	0	0	No treatment
Southern	Livingstone	Low	164157	0	0	0	No treatment
Southern	Mazabuka	Low	250275	0	0	0	No treatment
Southern	Monze	Low	211112	0	0	0	No treatment
Southern	Namwala	Low	116337	0	0	0	No treatment
Southern	Siavonga	Low	112606	0	0	0	No treatment
Southern	Sinazongwe	Low	115823	0	0	0	No treatment
Western	Kalabo	Moderate	113043	18550	2713	15837	Tx SAC Once yearly
Western	Kaoma	Moderate	173316	70054	6032	40469	Tx SAC Once yearly
Western	Lukulu	High	67192	27507	2687	15689	Tx SAC Twice yearly
Western	Mongu	Moderate	191186	31373	4588	26785	Tx SAC Once yearly
Western	Senanga	Moderate	109582	17982	2629	15352	Tx SAC Once yearly
Western	Sesheke	High	140903	57685	5636	32900	Tx SAC Twice yearly
Western	Shangombo	Moderate	166278	27286	3990	23295	Tx SAC Once yearly
Zambia		**Moderate**	**15585746**	**2743982**	**372093**	**1976977**	

Key: Tx= treatment; SAC=school age children;

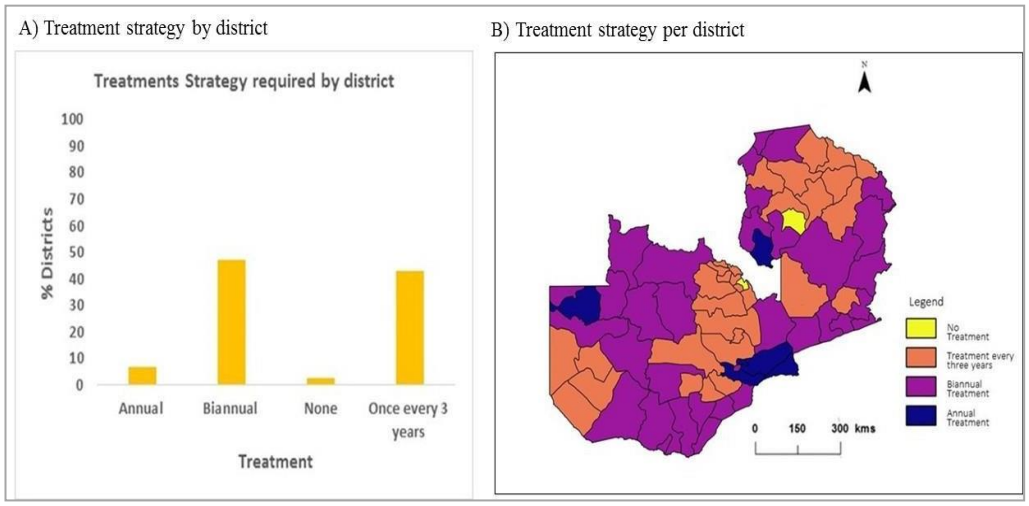


Figure 4-54 Graph and map showing Praziquantel treatment strategy by district for schistosomiasis

A) close to 50% of the districts will have biannual treatments and 7% annual treatments which is 34 and 5 districts respectively in B

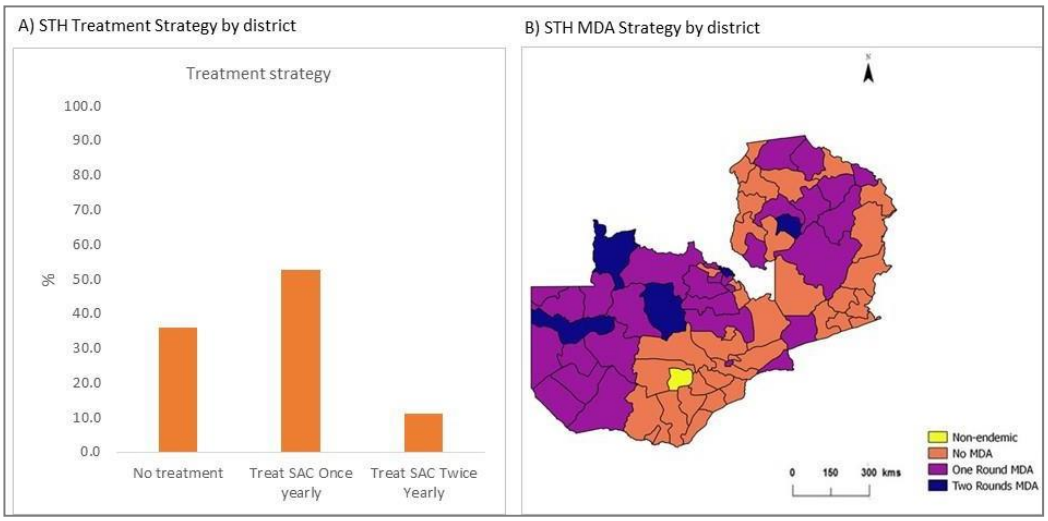


Figure 4-55 Graph and map showing mebendazole or albendazole treatment strategy by district for STH

In A, close to 50% of the districts will have biannual treatments and 7% annual treatments which is 34 and 5 districts respectively in B

4.5.8.3 Predicted and forecasts of the praziquantel and mebendazole/albendazole treatment needs

Based on the 2019 praziquantel requirement and the endemicity status, Table 4-17 shows praziquantel estimates for the next four years. A total of 15.7 million cumulative treatment are estimated for 2019-2022 period with an annual average of 3.9 million treatments tablets required in 2019 and a total of 42.1 million tablets by 2022.

Based on the 2019 Albendazole or mebendazole requirement for high and low risk communities based on the endemicity status, the Table below shows their estimates for the next four years. A total of 9.6 million cumulative treatment are estimated for 2019-2022 period with an annual average of 2.4 million (Table 4-18). Since Albendazole and mebendazole are calculated at a ratio of 1:1, these Figures also represent the total number of SAC that are expected to be treated under the NTD programme.

Table 4-41 Praziquantel estimates, 2019-2022

	2019	**2020**	**2021**	**2022**	**Total**
High endemicity	1804598	1985057	2183562	2401918	
Moderate endemicity	8183433		9820119	10802130	
Low endemicity	2440935	-	-	2461438	
TOTAL	12428966	1985057	12003681	15665486	42083190

Table 4-42 Albendazole/mebendazole, 2019-2022

	2019	**2020**	**2021**	**2022**	**Total**
High risk community	391970	431167	474283	521711	1819131
Low risk community	1688049	1856854	2042539	2246792	7834234
Total	2080019	2288021	2516822	2768503	9653365

4.6 Discussion

The study presents the first largest scale school-based surveys in the 10 provinces of Zambia. The study has indicated the presence of schistosomiasis and soil transmitted helminthiasis species through the presence of eggs in urine and stool collected from the children in the study population. The ongoing transmission is widespread and conforms with previous predictions especially of soil transmitted helminths in Zambia. Two test types (dipstick and urine filtration) used in the study reaffirmed the close association between dipstick test and urine filtration. The age group affected

the most is the 10-12 years and >15 years. Furthermore, univariate, and multivariate analysis revealed positive association between some environmental predictors for the different species and hookworm having the most correlation with temperature, precipitation and soil types. Therefore, a deeper understanding of the disease distribution for schistosomiasis and soil transmitted helminthiasis and their drivers for transmission is now established for Zambia.

This information will provide the evidence to the Ministry of Health and other sectors that have a role to play in addressing NTDs in the republic of Zambia. Planning for interventions including estimating the number of people requiring treatment for the next five years is now possible with the information produced by this research. The country should now capitalise on the strong and new global, regional, and country level momentum to scale up interventions for the two-preventive chemotherapy NTDs. However, my study did not assess the extent of morbidity occasioned by these two NTDs, and the snail prevalence and distribution to guide case management and environmental interventions, respectively. These will form part of the next research questions.

4.6.1 The transmission of schistosomiasis and soil transmitted helminths in Zambia

The distribution of schistosomiasis and soil transmitted helminthiasis in Zambia stems back to the 20th century (Buckley, 1946) with more studies conducted later in the 20th century (Siziya and Mushanga, 1996). Our recent national study shows that all the provinces are endemic for both SCH and STH, and all districts except Chilubi and Ndola for SCH. The distribution is at varying prevalence rates from low to moderate and high. The estimated national schistosomiasis prevalence of 16.6 % is considerably lower than the previously published based on the predictive maps of 27% (Ying-Si Lai et al., 2015). Additionally the observed national prevalence for the two Schistosoma species in my study is 15.2% (CI 13.8-16.6) for *S. haematobium* and 2.8% (2.3-3.3%) for *S. mansoni* which are below the predicted 23.1% (CI 19.2-28%) and 5.0% (CI2.9-8.9%) respectively (Ying-Si Lai et al., 2015). On the other hand, the *S. haematobium* results are more comparable with Baotin's national prevalence findings in 1985 of 16.8 %, and those for *S. mansoni* which fall within the range between 0-7 % (Boatin et al., 1985). The persistence of infection over the years maybe due to the risk factors that contribute to infection transmission. The

distribution is wide and could be attributed to the high contact with freshwater bodies distributed across the country (Chitsulo et al., 2000, Ndukwe et al., 2019). The lifestyles of the children and their families was not taken into consideration during the study which would have otherwise provided more data on the wide distribution. One of the factors could be that maybe because the main occupation is farming or fishing which allows frequent contact with the water and also children fishing, bathing, swimming, and washing clothes and dishes at the water bodies (Stothard et al., 2013a). However, due to random selection of the sample sites the aspect of purposeful selection of schools near the water bodies was not taken into consideration. The distribution is apparent in the cities as well as seen in Lusaka and Kafue districts with very high prevalence. Lusaka, which is also the capital city of Zambia has a high population in the peri-urban areas and these may have contributed to the high prevalence. Similarly, the infection rate is much higher in an exclusively peri-urban setting, even in the absence of any large nearby water bodies (Agnew-Blais et al., 2010). This underlines the importance of further investigations in the peri-urban areas in Lusaka and other cities that seemingly do not have large freshwater bodies but have high Schistosoma infection.

Overall STH prevalence in this study was 22.0 % (95% CI of 17.1-27.0) which is near a quarter of the population of Zambia being infected. The predominant parasite was hookworm which was distributed across the country at varying levels with a mean of 18 % (95% CI of 12.8-22.6) translating to approximately a fifth of the population being infected with hookworm. The fact that the prevalence of hookworm is almost equivalent to the prevalence of the combined STH, hookworm is outwardly the main parasite contributing to the STH infections in Zambia. Hookworm was also reported by Buckley and Clements in their studies as being universal and the main STH widespread in the country in different geographical zones (Buckley, 1946, Clements, 2005). At the provincial level, our study has shown that STH prevalence is highest in Northwestern and Western Provinces. However, this finding contradicts earlier findings and maps by GAHI, that show Southern and Northern Provinces having the highest rates (GAHI, 2009). Another interesting finding is the rather contradictory result between our results and Siwila's study results on *A. lumbricoides* and hookworm with prevalence of 12% and 8.3%,respectively, in Kafue district (Siwila et al., 2015) where the opposite was true in our

study as we found hookworm to be higher than *A. lumbricoides* in the same district. Indeed, all the previous studies have provided critical evidence that the problem has existed for a long time. However, considering the sample size, sample site selection and the large scale geographical coverage, it makes our more recent nationwide survey results more representative and should be used as evidence for the strategic direction of the NTDs programme in the country to address this public health problem.

Our study also highlighted the constant high prevalence rates for both SCH and STH in North-western and Western Provinces which both lie on the western part of the country. STH is most prevalent in humid, tropical and subtropical regions where adequate sanitation is lacking and is sufficiently moist to allow survival of worm eggs or larvae while for SCH in addition to lack of adequate sanitation requires presence of infected freshwater bodies near settlements (Yajima et al., 2011). In this regard, geographically, the presence of the two NTDs in the same area is highly possible, which has been the case in my study. It may also be an indication of low developmental projects going on in the areas especially the WASH projects as both STH and SCH are highly endemic in marginalised communities with poor WASH services (Chitsulo et al., 2000). *S. mansoni* specifically was highly endemic in these areas plus Southern Province unlike most parts of the country. It is not very clear why the central part of the country has low prevalence rates in comparison to many other areas. Could the answer be that this pattern could also be due to cross-border transmission? However, the transmission patterns especially for SCH, tend to be focal and may not be influenced by cross-border transmission but again this is something that would need further investigations. The contributing factors to these findings need to be assessed further, including factors causing the persistently high prevalence in the other areas too. A good surveillance framework to monitor human health and environmental health and the link should be established and strengthened in order to ascertain the causes of these concerns (Stothard et al., 2017a).

An interesting finding from the study is the revelation of the non-statistically higher positivity in males Vs females. It is a known factor that boys usually play and swim in rivers, dams and lakes exposing themselves more to infection. Our study found no statistical difference for *S. mansoni* and *T. trichuris* but significant

difference for the *A. lumbricoides*, *S. heamtobium* and hookworm where boys were more infected. It is not very clear why maybe exposure and infection of *S. mansoni* is the same in males and females and but different for *S. haematobium* and similarly, for STH infections. In our study we did not assess proxy markers for exposure such as distance to the infective water bodies for us to determine the reason why the difference in infections. The water body maps for Zambia without knowing infectivity may not be the ideal way of assessing this either. However, a study in rural fishing community in Uganda, showed that males had a greater likelihood of reinfection than females, mainly attributed to socio-cultural and behavioural factors but could also be due to susceptibility to infection (Stothard et al., 2017a, Kibira et al., 2019). In addition, a multidisciplinary study to look at the malacological,ethnicity and immunology influencers may also play a role in identifying the difference in infectivity rates by gender (Pinot de Moira et al., 2010).

The comparison between dipstick and urine filtration reaffirmed previous findings that haematuria by dipstick is a sensitive test by comparison with urine filtration (Sellin et al., 1982) as shown in the observed frequencies which were not statistically different from the expected frequencies. The two tests can therefore be used interchangeably in Zambia especially where there is high prevalence of *S. haematobium*.

The hot and cold spot clusters for the intestinal and urogenital schistosomiasis were found in different locations similarly, those for hookworm and *Ascaris*. However, hookworm and *S. mansoni* had similar hotspot clusters in Northwestern Province while *Ascaris* and *S. haematobium* had hot spots in Lusaka and the southern part of Luapula Province. These hot spots pose a higher chance of transmission of the parasites because it is not necessarily that where the hotspots are that is where the highest values are but the neighbourhood or parameter distance between values and the spatial relationship. The analysis of the hotspots should assist in focussing on specific areas for the control and elimination. The two fundamental parameters that classifies the country into hot and cold clusters will form an integral component for targeted interventions especially in resource constraint settings and where the program wants to make significant impact. Therefore, spatial clustering, and environmental analysis of at-risk population of school-age children requiring

integrated schistosomiasis and soil-transmitted helminth treatment regimens according to the identified co-distribution based on spatial clustering is priority for scale up of interventions.

4.6.2 Highlighting the environmental and climatic predictors of transmission

The environment and the climatic conditions play a critical role in influencing transmission and distribution of SCH and STH. For the study, I focussed on elevation, temperature, precipitation, and soil types for reclassifying and overlaying these factors as the main contributing factors identified. The study results have shown a large proportion of the study area fell in highly favourable conditions. It is not surprising that most of the predictors are conducive for hookworm. This relates very well as to why hookworm is the most prevalent STH NTDs in my study findings. The predictors conducive for hookworm included seven of the nine tested. These were mean annual temperature (good and very hot), minimum temperature coldest month (cold and very hot), precipitation driest month (heavy and small rains), clay topsoil (15 to 100 cm), pH (neutral and acidic; neutral and very acidic) and silt topsoil (15 to >100 cm). All these make it very favourable for hookworm to thrive and explains why it has the highest STH prevalence and endemic in all the districts except one. *A. lumbricoides* and *S. haematobium* were found to have four conducive predictors to thrive and makes them the next two NTDs highly endemic in the country. Mean annual temperature (good temperature), minimum temperature coldest month, pH (neutral and strongly acidic) and clay soil favoured *S. haematobium* while like *S. haematobium* and hookworm mean annual temperature (mean scores of cold and very hot), and pH (acidic and strongly acidic) where predictors for *A. lumbricoides* in addition to silt topsoil and precipitation wettest month. However, *S. mansoni* only flourished in precipitation wettest month and surprisingly like STH in clay topsoil. Elevation levels and sand topsoil type did not play a major role in the thriving and transmission of the STH and SCH in Zambia. Elevation is a significant determinant of suitable altitude that influences temperature for the parasites to survive.

Soil is the main ecological reservoir for STH eggs prior transmission. The incubation period for the three species varies from 1-14 days at temperatures below 40° C for hookworm to 5-38 days at 5-38° C for *A. lumbricoides* and 20-100 days at

5-38°C for *T. trichuris* (Brooker et al., 2006). Considering the predictors in my study, the incubation durations, temperature, precipitation in the driest month with a neutral and acidic clay or silt provides the moisture conditions required for incubation, explaining why hookworm is highly endemic in Zambia. The long incubation duration for *T. trichuris* at certain temperature may explain the reason why there is hardly *T. trichuris* in the country based on my study findings. Another explanation could be the mode of transmission since hookworm penetrates through the skin adds on to easy transmission as most children in Zambia in the remote and peri-urban areas do not wear shoes all the time exposing them to infection. Geophagia occurs in many parts of the country and inadequate WASH facilities may explain *A. lumbricoides* infection which also has a short incubation period. The limitation in my study is lack of soil sampling to confirm the concentration of the ova in the soil and the distribution.

The conducive warm temperature in the tropics and subtropical propagates the transmission of SCH and STH. Multivariate analysis on temperature (mean annual temperature, maximum temperature hottest month and minimum temperature coldest month) clearly showed how temperature is critical in the survival of all the species in my study including the intermediate host (snail) for Schistosoma. Low temperature specifically affects the cercarial release for *S. mansoni* (Toledo, 2011). This is reflected in my study where the focal areas of *S. mansoni* was in the Southern and western parts of the country where the temperature is normally high three quarters of the year.

Normally schistosomiasis thrive at elevations between 800-2200m (Ajakaye et al., 2017). It is strange that my study did not reveal any possible impact of the elevation on the parasites. Our findings are not consistent with the finding in Uganda where the natural transmission of *S. mansoni* was found to be high in altitudes between 1000-1400m (Stanton et al., 2017) considered as best altitude for survival for schistosomiasis and *Ascaris*. Schistosomiasis is inevitably influenced by warm climate as both the schistosome parasite and its intermediate host snails are highly sensitive to changes in water temperature due to altitude (Stensgaard et al., 2016). New areas may become suitable for *S. mansoni* transmission, and currently endemic areas may experience change in prevalence. The correlation in Zambia is poor and

more modelling to ascertain the association is necessary. In as much as the current endemic areas for *S. mansoni* are warm, there was no association found. Western, Northwestern and Southern Provinces have high temperatures hence the identified evidence of focalised endemicity status in the three main provinces of Zambia.

One challenge is the climate change which is expected to impact across every domain of society, health including NTDs whose lifecycles are sensitive to environmental factors such as air, water and soil (Booth, 2018, Booth and Clements, 2018). It is possible that places that were considered unfavourable for transmission of parasites may now become favourable and those favourable may become unfavourable. If that were the case where climate change may be extreme enough to cause elimination or extinction of parasites (Cable et al., 2017), it could benefit the programme in Zambia since most endemic districts were found to have moderate or low risk. In view of this, climate change may have a large effect on both the distribution and intensity of *S. mansoni* which may reduce the effects of control and elimination tailored only in currently known endemic areas which also experience high temperatures and are therefore the hottest areas in the country. Due to climate change there is a threat of spreading to other areas outside the localised areas in Southern and Western parts of the country (McCreesh et al., 2015). However, too much heat may also lead to large fluctuations in numbers of snail species e.g. *Biomphalaria* where fecundity was shown to have decreased (McCreesh et al., 2014). Detailed insights into the causes and drivers of climate change have been discussed by Mark Booth demonstrating a range of scale within ecological, biographical, social and geographical domains of organisation that will be affected directly or indirectly by climate change (Booth, 2018). More research to mitigate the adaptive change in parasites and analyses models for specific areas are needed to fully understand parasites and snail's survival with changes in climate as most of the information is based on previous studies before the current rapid ecological and community change (Booth and Clements, 2018). With the possible impact of climate change on transmission of NTDs, surveillance should be enhanced to ensure the country does not miss any risk of an increase in prevalence to put mitigation measures or a decrease the risk of transmission. There is paucity in malacological and epidemiological data pertaining to schistosomiasis in Zambia which also needs to be further researched to have a comprehensive and more informed dataset. The prevailing geographical and

climatic conditions during the study promoted the transmission of STH and SCH in Zambia. The null hypothesis test that there is no correlation between SCH and STH with the environmental and climatic predictors in Zambia is rejected. We are 99% confident that there is association between SCH and STH with the predictors as indicated in Tables 4-9 to 4-33.

4.6.3 Donated or purchased medicines

One greatest achievement of the endorsement of the 2012 London Declaration (UTC, 2012) on the control and elimination of neglected tropical diseases, is the commitment of the pharmaceutical companies to scale up production of praziquantel and other preventive chemotherapy NTD medicines to meet the global demand (UTC, 2017a). The declaration has brought up a lot of dramatic change including closing the treatment gap faced by most endemic countries and the resolution passed by the World Health Organisation in the same year to eliminate schistosomiasis which has given hope to many countries including Zambia. Since 2007 Merck has donated praziquantel through WHO to countries to implement elimination programmes. Merck's pledge is to donate 250 million tablets per year to control morbidity due to schistosomiasis, mainly in school aged-children in sub-Saharan Africa https://www.merckgroup.com/ro-ro/company/responsibility/our-strategy/health/schistosomiasis.html and GlaxcoSmithKline (GSK) has committed to donate albendazole 400 million tablets every year to treat intestinal worms in addition to the ongoing commitment to supply the WHO with 600 million tablets for LF MDAs http://www.gsk.com/en-gb/media/press-releases/gsk-increases-support-for-who-strategy-to-improve-children-s-health. If the Merck donation was not available, Zambia would be paying $88.09 for 1 bottle of 1000 tablets of PZQ and ALB that cost 4 cents would be costing $400. The risk estimates of infection in the population and the amount of the required PZQ and ALB or MBD, according to the endemicity, is possible and has been calculated. In support of the World Health Assembly resolution 54.19, which urge member states to treat all at risk populations through mass drug administration as preventive chemotherapy of helminthiasis (World Health Organization, 2001), the total population at risk of infection for SCH at >0.1% is 12,044,600 and STH in endemic districts above 20% is 9,569,823. Therefore, a total of 42,083,190 PZQ tablets needed over a period of four years would cost $3,707,108. 21 while 9,653,365 ALB tablets would cost $1,930,673. This is money

that a developing country like Zambia could not pay through domestic funding. In order to benefit from the pharmaceutical donor support, Zambia has to intensify its interventions to control and subsequently eliminate SCH and control STH. The target age group for the NTD programme is SAC while the Pre-SAC receive treatment at the under-five clinics and pregnant women at antenatal clinics. Studies have shown that 20 % of any population with intestinal parasites host 80 % of the worm population in an area and can spread the infection to others, as they pass the parasite eggs in their faeces (WHO, 2011). WHO guidelines therefore, suggest the target treatment coverage should be at least 75 percent of SAC or the population at risk during each administration of the pills (Gabrielli et al., 2011), so as to limit the chances that infected people in the community can pass the worms easily on to others, or cause reinfection. In Zambia more than 50% of the population are amenable to treatment for both PC NTDs. My study results have provided the basis to synthesise information on medicine for SCH and STH in Zambia. This will enable the programme to plan adequately for the national large-scale treatments and meet the relevant target goals for control and elimination of the diseases. District verses subdistrict treatment for SCH has been debated and now WHO is advising countries to be mindful of the resources and advising countries to implement at the subdistrict level due to the focal nature of SCH (Engels and Zhou, 2020).

Preventive chemotherapy is a public health intervention strategy that focuses on large-scale administration and a gateway to universal health coverage. The challenge comes in when completing the request form to WHO. In the Joint Application Package based on the categories of low, moderate and high-risk areas. The three categories which have different treatment strategies make it difficult for the country programme to follow effectively (World Health Organization, 2013g, Gabrielli et al., 2011). Calculating a third of SAC to be treated in low endemic districts every year or 50% of adults to be treated every second year in moderately endemic districts or all SAC and adults in high risk areas especially that the implementation unit is a district. The guidelines for this should be revised and made simpler and cost effective to have a more focalised treatment programme in those endemic communities that require treatment. The good will from the pharmaceutical companies should be met by effective implementation of MDAs with little wastage of medicines.

4.6.4 Insights into the disease burden to guide schistosomiasis and soil transmitted helminthiasis programmatic roadmap

In general, both schistosomiasis and soil transmitted helminthiasis are widely distributed in the country with the highest concentration in the north-western and central parts of the country. The results are alarming, and some schools recorded 100% infection indicating that both girls and boys were equally infected in these schools. A general finding across the country was that boys were generally more infected than girls but there was no statistical difference for *S. mansoni* and *A. lumbricoides* but for the other three species. A few schools were comparable between boys and girls within each school and between boys across schools. This feature is not new to Zambia as similar findings were also observed in Osun State, Nigeria (Oladejo and Ofoezie, 2006). Further, due to the non-existence of national control programme, there is an assumption of additional infections every year whichincreases with age. In the Zambian situation, 10 −12-year olds and the above 15 years(even though the population sampled for this age group was smaller) had high prevalence. This was not the case in the Namibia where the older age group where not affected because there was no continuous transmission throughout the years which could be due to break in exposure when there are no floods (Sousa-Figueiredoet al., 2015). The older you are the more recurrent infections due to persistent exposure throughout the year in some areas. A possibility that is presenting in Zambia. The poverty levels in the country and the daily lifestyle of most of the peopleespecially those living in highly endemic remote or peri-urban areas (marginalised communities) suffer the consequences. Zambia should therefore prioritise these communities and ensure yearly treatments to reduce morbidity and reinfection rates.

Reinfection is an issue that requires concerted efforts to address. A similar situation was observed on the shores of Lake Victoria and Lake Albert in Uganda, where the reinfection rates where high when they were followed up six months after praziquantel administration (Stothard et al., 2013a). This is likely due to very high levels of rapid reinfections and or inability of single treatment to cull all adult worms inside the body. There are some areas in Zambia that we found with high disease burden which may require frequent treatment and follow up after commencement of treatment to make sure infections and possible re-infections are under control especially in the hotspots. In this case regular impact assessment surveys and

possibly provision of additional health promotive education for social behavioural change and environmental improvement should be strengthened to avoid the picture that is pertaining in Uganda. Even so, with no proper interventions and persistent infection transmissions from as far back as the 19th century, reinfection is inevitable in the country. The biggest strength we have now is the massive study conducted in the whole country which has provided nationwide distribution. We now need to plan for interventions.

The stratification of the results according to the age groups revealed that 66.3% of the participants found with parasitic infection in Zambia was in the school age group. Similar results have been observed in many African countries. This is highlighted in in a scoping review on moving from control to elimination of schistosomiasis in sub-Saharan Africa, where school-aged children and pre-school children had the largest number of adult worms with copious tissue entrapped eggs (Tchuem Tchuenté et al., 2017). This key feature of high infection in the 10-14 years old is a key driver behind the impetus that overt morbidity commonly attributable to schistosomiasis can occur during school age (Stothard et al., 2013b). Morbidity due to schistosomiasis is a major concern in the control programme. The major strength from the study is the massive coverage of the whole country which has provided the nationwide distribution of schistosomiasis and demographics enhancing epidemiological evidence to inform policy and programmatic planning. The limitation is the lack of morbidity data (i.e. the extent of morbidity and parasitic intensity due to schistosomiasis. This coupled with nutritional status and other related complications of schistosomiasis such as hepatosplenomegaly, anaemia and bladder pathologies should be investigated further and form a base when it comes toassessing the impact of the interventions that will be put in place.

It is important to note the gaps that have been identified in the WHO supported programmes. Treatment for SCH and STH under the NTD programme is only donated to the SAC population living in endemic areas. The drug request form submitted to WHO clearly outlines the total population at risk and requiring treatment which include pre-SAC, SAC and adults. However, when the medicines are calculated to send to a country, only treatment for SAC is provided. If we are going to eliminate SCH like the new WHO AFRO guidelines state, more medicines should

be donated to the countries so that the entire population at risk can receive the medicines. This can be made even more cost effective by treating all eligible populations in high risk communities or subdistrict level. So that not the entire district receives the medicines but the pre-SAC, SAC and adults that live in these endemic areas.

4.6.5 An oversight of the whole process for surveillance

The importance of surveillance in an elimination programme is very critical and forms the core intervention. A strong surveillance system as part of health systems strengthening should and requires a lot of support. The information from a strong surveillance system will be able to monitor the trends of the disease, a recrudescence of the parasite and also the impact of the interventions that are being put in place. The steps to elimination of a SCH and STH requires concerted efforts from the WASH program, vector control, preventive chemotherapy and morbidity management as recommended by WHO. Impact assessments after 3 to 5 rounds of treatment with very good treatment coverage of over 75% of the target population is critical. However, while it may seem easier to prove something is there and interventions are being implemented as prescribed, there will be need for sufficient proof of control and possible elimination as evidenced by absence of transmission especially in the hot spots after, a certain number of rounds have been achieved making surveillance an essential part of the intervention package.

Zambia lacks a strong surveillance system for NTDs. There is therefore a need to establish surveillance to ensure universal access to diagnosis and reporting for schistosomiasis. The country will need to develop and strengthen supportive supervision for NTD Surveillance and develop NTD Communication and linkages with communities and clinicians and strengthen NTD monitoring for action including, collection and use of programme performance and operations data for action, which will inform the programme whether to scale down and verification of elimination. Regular review meeting on surveillance should be enhanced with proper documentation of the action points and timeline. With the strengthened surveillance system, detection of new cases will be enhanced. With the recently detected new hybrid of *S. haematobium* group S. *haematobium–mattheei* and *S. haematobium–bovis* in Malawi (Webster et al., 2019), new threats and zoonotic diseases are

emerging with combinations of genetic markers. The surveillance officers should have the necessary tools and skills to be able to overcome such emerging challenges and progeny, even though the new species is not yet detected in Zambia. Perhaps another consideration by the ministry is to embrace the OneHealth focussing on zoonotic diseases that can spread between animals and humans as is the case of the new hybrid in Malawi. The government of the Republic of Zambia has recently developed Health in All Policies, but its implementation has not yet been effected. It is on this platform that OneHealth should be advocated for to strengthen surveillance structures between Ministries of Health, Livestock and Agriculture. Since many of the same microbes infect animals and human's epidemiological data and laboratory information should be shared across sectors to effectively detect, respond to, and prevent outbreaks of zoonoses. Elimination of a disease when there is animal infections is a big challenge. This is also being observed in the Guinea worm Eradication programme where countries are failing to eliminate as the transmission is now being seen in domestic and wild animals as is the case in Ethiopia and Chad (Galán-Puchades, 2020b, Galán-Puchades, 2020a).

4.7 Conclusion

The present study has provided rates and the distribution of schistosomiasis and soil transmitted helminthiasis in the 72 districts of the 10 provinces of Zambia, adding to the previous sporadic studies conducted and closing the information gap on the national distribution of the two diseases. The new knowledge on the occurrence of infection is high enough to warrant implementation in the population at risk and requiring treatment. Preventive chemotherapy under the NTD programme should target all the eligible population including Pre-SAC and adults. National scale-up of the MDAs to catch up on the lost time. In light of the hot spots of the SCH and STH species, the country requires concerted efforts and effective policy to interrupt SCH and STH transmission with a focus on multisectoral approach with the WASH partners and sectors which will require coordination and synchronisation of efforts. The two tests for *S. haematobium*, dipstick and urine filtration can be used interchangeably to monitor infection in very highly endemic areas. It is now evident

why hookworm is the most prevalent of the five species because the environmental and climatic predictors were conducive for hookworm.

Although my study has generated evidence for a national SCH and STH programme, useful information to further improve programme implementation is required. There is need to assess the persistently high prevalence of *S, mansoni* in Southern, Western and North-western provinces including the burden and management of its complications. The country also needs to collect data on malacology and epidemiology is recommended for a more comprehensive programme. Besides there are still grey areas around the immune response to *S. haematobium* and *S. mansoni*, and hookworm and *A. lumbricoides*, the unequal distribution in females and males for different species and the unusual low correlation between SCH and STH prevalence with elevation.

Chapter 5 Policy Analysis for the NTD Programme in Zambia

5.1 The international agenda

In 2006, the World Health Organisation established an NTD Department in the Headquarters Office, Geneva and two years later the first Global Plan of Action 2008-2015 was developed which was based on the deliberations or debates on the strategy held by WHO and The Carter Centre on whether the control and eliminationof NTDs were possible (Donald et al., 2006). In the interim, in 2007, there was a general global momentum to overcome NTDs and the Global Partners met to discusshow they were going to support (in terms of time, effort and resources) in the fight to defeat these diseases of poverty (Hotez et al., 2007, World Health Organization, 2007). This was one of the biggest advocacies for NTDs as it declared to the world that NTDs deserved high priority on the global public health agenda for control andelimination. In 2010, WHO produced the World Health Report with a focus on health system financing as a path to universal coverage using the evidence of the devastating incidence of the people in rural areas (World Health Organization, 2010). In 2012, based on the evidence available about the NTDs including the Global Action Plan for NTDs, an NTD Roadmap 2012-2020 was produced which highlighted the 2015 and 2020 targets and interventions to tackle NTDs (World Health Organization, 2012a).

More momentum grew to fight NTDs and in the same year a landmark in public health cooperation was shown during the London Meeting when partners endorsed renewed commitment to support NTDs and the set ambitious agenda to fight NTDs for the ten years. The Bill and Melinda Gates Foundation donated $363 million and twelve of the world's biggest pharmaceutical companies collectively committed to extend their donations through 2020 to help meet the control and elimination goals set by WHO (UTC, 2012). A few success stories on NTDs have been recorded since the London declaration in 2012. Stronger Public Private Partnerships (PPP) have been created as the global collaborative effort has seen NTDs receiving more attention which has led to an increase in the number of people receiving treatment for NTD (World Health Organization, 2020). In 2016 one

billion people received treatment for at least one NTD and over 400 million people no longer required treatment for one of the NTDs (World Health Organization, 2017a). Five countries have eliminated trachoma as a public health problem since 2012 and 544 million people no longer need treatment for LF globally an indication that it is possible to eradicate NTDs if there is government or programme commitment and partner collaboration. The collective responsibility donors, pharmaceutical companies and governments have put in has been able to see countries reach the unreachable populations, attain UHC for NTDs and progress towards the control and elimination of NTDs. The WHO Roadmap to accelerate work to overcome the global impact of NTDs guides implementation of the policies and strategies set out in the Global Plan to combat NTDs (Hotez et al., 2007, World Health Organization, 2012a).

Furthermore, in the same year, 2012, the United Nations General Assembly endorsed a resolution urging countries to accelerate progress toward UniversalHealth Coverage (Nations, 2012) and five years later, 12th December 2017 was proclaimed International Universal Health Coverage Day (Nations, 2018), in an effort to promote health and ensuring that people get the health care they need. UHCis underpinned by equity, quality and affordability. UHC is embedded in Sustainable Development Goals (SDG) 3 (to ensure healthy lives and promote well-being for allages) with a set target to "Achieve universal health coverage, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all" (Nations, 2015). These can be achieved through primary health care (PHC) which is the cornerstone that sustains health systems as an inclusive, effective, and efficient approach promoting equitable access to quality and effective health care without catastrophic payments.

The NTD programme strategies including preventive chemotherapy, form an excellent example of how UHC can be attained. In order to support the attainment of UHC and leaving no one behind, the WHO 2019-2023 five-year work programme has a "triple billion" target of which the first goal is 1 billion more people benefiting from UHC by 2023 which will, among the ten challenges WHO identified, address the weak primary health care in many countries. The second goal is 1 billion more

people protected from health emergencies and the last goal is ensuring better health and well-being for 1 billion more people (World Health Organization, 2018a).

Additionally, the set target 3.3 of SDG 3 indicates that "By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases" which will be monitored and evaluated by the number of people requiring treatment and care for any one of the NTDs targeted by the WHO NTD Roadmap and World Health Assembly resolutions and reported to WHO. The NTD roadmap guides the implementation of the policies and strategies set out in the Global Plan to combat neglected tropical diseases by eliminating them and reducing morbidity and transmission significantly. The control, elimination, and eradication of NTDs can be attainment with serious commitment to treating the populations at risk with a very high coverage as a gateway to UHC. This can be sustained with full implementation of WASH (World Health Organization, 2017c), vector and intermediate host (Wilson et al., 2020) coupled with awareness campaigns (World Health Organization, 2012a, World Health Organization, 2013c). It is anticipated that control of these diseases will significantly reduce illness, social exclusion and mortality and contribute directly to the attainment of several Sustainable Development Goals.

5.2 An inclusive NTD policy in Zambia

Zambia's aspirations to become a middle-income country by 2030 (Government of the Republic of Zambia, 2006, Government of the Republic of Zambia, 2017a) is only possible if the health status of the people improves to contribute to the socio-economic development. Zambia is a low-income-country with a Gross Domestic Product of $26,720 million in 2018 (https://countryeconomy.com/countries/zambia) which places it at 155th position of affluence out of 196 countries. Most places especially in the rural and peri urban areas are yet to develop and lack basic water and sanitation amenities. People living in these communities also have their own misconceptions about NTDs and other diseases and have strong cultural background and norms with limited understanding on NTDs in terms of transmission, prevention and treatment. Zambia is also a democratic country with a relatively stable political system. It has changed leadership seven times in the last 28 years. Some situational factors such as the realignment of the Ministry of Health where PHC was moved to

a newly created Ministry of Community Development Mother and Child Health in 2012 (Government of the Republic of Zambia, 2012) have affected the implementation of NTD interventions in the country. This created a lot of misunderstanding in terms of administration and provision of health services. All the six building blocks of the of health system strengthening were affected at that time. This policy was then reversed in four years later when the Ministry of Health took up the responsibility of PHC. Relatively, permanent environmental and geographical factors described in the previous chapter have also contributed significantly to the NTD programme.

The country has developed National Health Strategic Plan 2016-2021 with a vision of having 'A nation of Healthy and Productive People', while the mission is 'To provide equitable access to cost effective, quality health services as close to the family as possible', with the pursuance of a national goal which is 'To improve the health status of the people in Zambia in order to contribute to increased productivity and socio-economic development (Government of the Republic of Zambia, 2017a). Considering the vicious cycle of poverty that comes with morbidity and debilitating disabilities from NTDs, addressing the high burden of NTDs in the country, will positively contribute to the national goal. In this regard, the focus should be to improve the health of the people by increasing treatment coverage and strengthening health systems making them robust and resilient. If all Zambians are to be reached, primary and community health approaches should be the focus.

All aspects of health from health education, disease prevention, early detection to treatment, rehabilitation and palliative care are very critical. This will enhance the attainment of Universal Health Coverage without leaving anyone behind and as such the key outcomes of the NTD programme can be sustained. The distribution of the three PC NTDs is wide in the country with all 72 districts being endemic for STH, 69 for SCH and 56 for LF. However, the status of the interventions requires scaling up for STH and SCH which are at 58 % and 30% treatment coverage, respectively, while LF is now scaling down with 93% treatment coverage. This is based on the score card which is critical and uses the most up to date data from the countries to track progress (UTC, 2017b). Other key performance indicators for the programme will be obtained from the Joint Application Package for PC NTDs which

has the Joint Request Form for Specific Medicines (JRSM) for the MDAs, the Joint Reporting Form (JRF) for PC NTD and the Epidemiological Data Reporting Form (EPIRF)" during the investigations as part of the policy analysis process for additional facts and Figures later on in the chapter. For the NTD programme to be successful in Zambia the strategic direction should be based on the implementation of the NTD global roadmap, the regional NTD targets and goals and on the government commitment during the regional committee meeting and monitored by the SDG 3.3 indicator.

5.3 Problem Statement

Zambia is in the process of scaling up the implementation of NTD interventions based on the study findings. It has been noted that two (SCH and STH) of the three major PC NTDs (with LF) are not being addressed adequately in Zambia despite the available evidence of ongoing transmission. Sustainability of the programme is also uncertain. It is not clear as to why the two NTDs programmes are not advancing and the LF is making good headways. Therefore, these problems deemed it fit to first review the extent of the problem through research and come up with a possible solution. The description of the Zambia policy analysis will define the problem, assemble evidence and make recommendations based on the strategic direction provided by the global NTD roadmap, international and national levels.

5.4 Aim and Objectives

The aim of this chapter is to provide an overview of the national health system/structures and examine how the NTD programme in Zambia aligns with the WHO Roadmap by comparing the key indicators and the action points, main targets and the milestones and well-founded prospects for the future.

Objectives:

1. To provide a general synopsis of the Ministry of Health and the NTD programme.

2. To undertake a desk-based review on what progress has been made and the current gaps in the implementation of the WHO NTD Roadmap, 2012-2020.

3. To identify the influencers of NTD Health Policies and review the key actors driving the process in the Zambia NTD programme.

4. To identify critical actions and solutions to be taken towards the strategic direction.

5.5 Methods

The research on policy analysis for the NTD programme in Zambia was mainly through questionnaire, discussions, getting viewpoints and experiences of NTD control programmes regarding general health services, community interventions and vice versa. The study used a strong internally coherent approach within the NTD unit and constructive discussions towards complementarity with the various departments in the ministry. Therefore, data used in this analysis was obtained from different sources which include individual interviews using a questionnaire (Appendix 4 Tool 4) and desk review secondary data from Ministry of Health documents such as strategies, policies, plansof action and implementation status of the NTD programme in order to identify significant features that could have an impact on the NTD programme in Zambia. Focusing on these helped pave way for fruitful synergies. The internet was another source to bolster literature coverage. In some instances, where the information was not clear from the documents within the ministry, a face-to-face engagement of the key individuals were consulted for more in-depth information of any identified problem.

The WHO-recommended strategy for interrupting transmission is preventive chemotherapy and transmission control (PCT), mainly through MDA using the specific medicine combinations for the endemic NTDs. This study reviewed the current global and regional treatment strategies for transmission control of LF, STH and SCH and discusses the challenges posed by the NTD programme and the fragile primary healthcare system in their implementation. The role of integration including vector management as a supplementary strategy for transmission control, the strategy for treatment and morbidity control, advocacy and WASH were also discussed. The assessment of the data obtained revealed the achievements, gaps, and challenges from where possible critical actions (relationships, integrations, and the alternative

course of action), the different policy options, and strategic directions to address the problems. The findings also brought out areas that require additional research.

5.5.1 A general description of the Ministry of Health and the NTD programme.

I described the ministry of health systems through consultations with the policy, planning, human resources, and administration departments within the ministry and how the NTD unit fits into the overall structure. From the findings, I created an organogram of the current MoH structure, described the various components of the WHO health systems strengthening in service delivery and how each of the six building blocks is implemented in the Zambia and to the NTD programme. In order to understand the focus of the Ministry of Health and the national health strategic direction I carried out a desk review of the health strategies, health policies and the national prioritization of strategic interventions that are aimed at attainment of specific objectives under the Health Service Delivery System, the Integrated Health Service Support Systems and their support to the NTD programme.

5.5.2 A desk review of the implementation of the WHO Roadmap and the National NTD Plan

A comparison of the implementation of the NTD strategies of the primary interventions and indicators from the WHO Road map and the regional NTD Action Plan with the Zambia NTD strategy was assessed. This was used to determine feasibility of elimination according to the targets for 2020. The ultimate end point of this roadmap is the elimination of NTDs or reductions in their impact to levels at which they are no longer considered public-health problems at which point the core intervention is surveillance. Realistic strategies and targets to achieve this goal are set out. These include the following:

1. WHO Roadmap

A) Strategies for the control, elimination, and eradication of NTDs

- preventive chemotherapy
- intensified case management,
- integrated vector and intermediate host control,

- veterinary public health at the human-animal interface,
- provision of safe water, sanitation, and hygiene

B) Target and milestones for the control and elimination of NTDs

- Global Elimination of LF by 2020
- Elimination of schistosomiasis in selected African countries by 2020
- 75% of preschool and school-aged children in need of treatment (intestinal worms) are regularly treated with a national plan of action

2) Regional Action Plan 2012-2020

A) Primary interventions outlined in the for the three NTDs

- lymphatic filariasis: Preventive chemotherapy and morbidity management and disability prevention
- Schistosomiasis: Preventive chemotherapy
- Soil-transmitted helminthiasis (STH) Preventive chemotherapy

B) Targets of the three NTDs in the African Region and feasibility for elimination 2020:

- Elimination of LF by 2020
- Elimination of schistosomiasis by 2025
- Deworming coverage of 75% of preschool and school-aged children at risk of STH by 2020.

The documents reviewed included the National Health Strategic Plan 2016-2021 for the Ministry of Health, Zambia. The key performance indicator is zero number of districts endemic to lymphatic filariasis, schistosomiasis and soil transmitted helminthiasis by 2020. The programme key performance indicators will be obtained from the Joint Application Package for PC NTDs which has the Joint Request Form for Specific Medicines (JRSM) for the MDAs, the Joint Reporting Form (JRF) for PC NTD and the Epidemiological Data Reporting Form (EPIRF) which indicate

What has been done Reference will also be made to the National NTD Master Plan. The forms report on the following:

Joint Request Form for Specific Medicines

- Information about the PC medicines requested from HQ required, in stock, in pipeline and requested
- Number of people to be treated with the donated medicines
- Dates of the planned MDAS for the various rounds and date by which the medicines should be in
- Information of medicines requested for MDAs not donated by WHO

Joint Reporting Form

- Endemicity status of the implementation unit
- Planned interventions
- Population requiring treatment by age group
- number of people received treatment at least once in that year for the disease
- the coverage for PC interventions for the diseases both geographical and national
- number of people treated and programme coverage (and therapeutic coverage) by PC interventions
- inventory of PC medicines in the country

Epidemiological Data Reporting Form

- Indicators on the epidemiological data on LF and the morbidity management and disability prevention
- Indicators to report epidemiological data on STH and SCH including the species specific and intensity.

In order to guarantee effective implementation of the five strategies highlighted in the five WHO NTD Roadmap implementation framework, several key interventions and activities are required. These interventions were identified and put in a Table and were compared with what has been done in the country. The focus was on the tools, planning, coordination, capacity building, interventions, monitoring and evaluation and research. WHO recommends implementation of six building blocks to strengthen health systems which include the delivery of safe quality assured interventions, health workforce that is responsible and effective, information systems, equitable access to medicines, health system financing, leadership and governance. These werefurther broken down to specifics that relate to the NTD programme. Gaps were identified in their implementation and recommendations made for future inclusion. This section was grouped into tools and guidelines established for various focus areasand the review of the building blocks for health system strengthening. A score was assigned according to the implementation status to better determine the degree to which an indicator has been met. Each indicator was scored from 0-3 as follows:

- 1= nothing is being done or emergent (early stage or being developed)
- 2=starting/beginning/commencement implementation or developing (good progress in building and using evidence
- 3= partial implementation or satisfactory (significant results demonstrated in most but not all target areas)
- 4=full implementation or strong (results demonstrated in all key targeted areas)
- 5=not applicable

5.5.3 Influencers of the NTD Health Policies and review the key actors driving the process of the Zambia NTD programme

The paragraph defines and reviews the influencers of the NTD policy in Zambia at the global, regional and county levels by conducting a systematic search in Cochrane, google, WHO websites, Medline databases and review of documents from the ministry's departments of policy, planning and budgeting in the Ministry of Health. Papers were selected and evidence reviewed, and I made a subjective judgement.

These were analysed to identify the gaps and recommendations on what needed to improve. A prediction of the next steps and the possible consequences of the *status quo* was documented.

5.5.4 Policy gaps and solutions in the delivery and coverage of interventions for LF, STH and SCH

Based on the assessment in 1, 2 and 3 above, this section reviewed what is being done that does not fit well for Zambia. In the sections, strategies or interventions withlow scores, what could be causing that and what the possible solution is to the identified problem were documented. In the areas with high scores what could havecontributed to the success was assessed. The identified gaps led to the identification of the solutions or alternatives and how these will then be evaluated in terms of effectiveness, their relevance, progress, efficiency and impact at individual, family, community and national levels. Trade-offs to the programme at this point were identified and what to focus on to reach the targets.

5.5.5 Limitations

My study cannot be used to establish cause and effect relationships on the data sets collected especially on the implementation. Given the practical nature of the synthesis question, no formal inclusion or quality assessment criteria were used. Another limitation is policy analysis at this level of having been an insider position was the preconceptions held by the interviewees in providing responses based on assumptions they had in relation to my views as a result of my work history with the interviewee categories and through MoH document reviews, of which I was a part of at one time and provided guidance. Getting information on interventionsimplemented at the community at national level may have some bias.

5.6 Results

5.6.1 Part 1: National Health System overview

The transformation agenda of 2016 in the ministry brought the introduction of new departments and removal of some. Previously the ministry had a Deputy Minister, but this position was abolished and a second position for the Permanent Secretary (PS) created to oversee administration of the ministry whilst the other PS

superintends the health/technical services as shown in Figure 5.1. The two PSs report directly to the Minister of Health. Statutory bodies of the ministry report either through the PS to the Minister or directly to the Minister. A total of 11 departments and units report to the PS Administration and these include Human Resource Planning and Development (DHRPD), Administration (DA), Policy and planning (DPP), Accounts, Health Care Financing (HCF), Information Communication and Technology (ICT) Procurement and Supplies (PSU), Physical Planning and Medical Technologies (DPPMT), Legal, Internal Audit, Human Resource Management (DHRM) while 9 directorates report to the PS Technical Services and these include Public Health (DPH), Clinical Care and Diagnostic Services (DCCDS), Health Promotion Environment and Social Determinants (DHPESD), Global Health (GH), Performance Improvement (PI), Quality Assurance (QA), National Malaria Elimination Centre (NMEC), Nuclear Medicine (DNM) and Nursing Services (DNS).

All these in one way or the other can contribute to the NTD programme but the programmes and departments in most instances run parallel despite a lot of cross cutting areas such as performance improvement, community health, quality assurance, public interventions and communication or health education . The national level is responsible for overall coordination and management, policy formulation, strategic planning, advocacy, and resource mobilization. The Provincial Health Directors (PHD) work with all the directorates and report to the Permanent Secretaries. The Provincial Health Directors are responsible for health management in the 10 administrative provinces and cover 72 (plus 33 new districts=105) districts which are run by the District Health Directors and statutory bodies.

At the central level, the NTD unit falls under the directorate of Public Health and reports to the Assistant Director responsible for infectious or communicable diseases as indicated in Figure 5-2. The NTD Programme Manager is assisted by four Chief NTD Officers who each has been given a responsibility of NTDs.

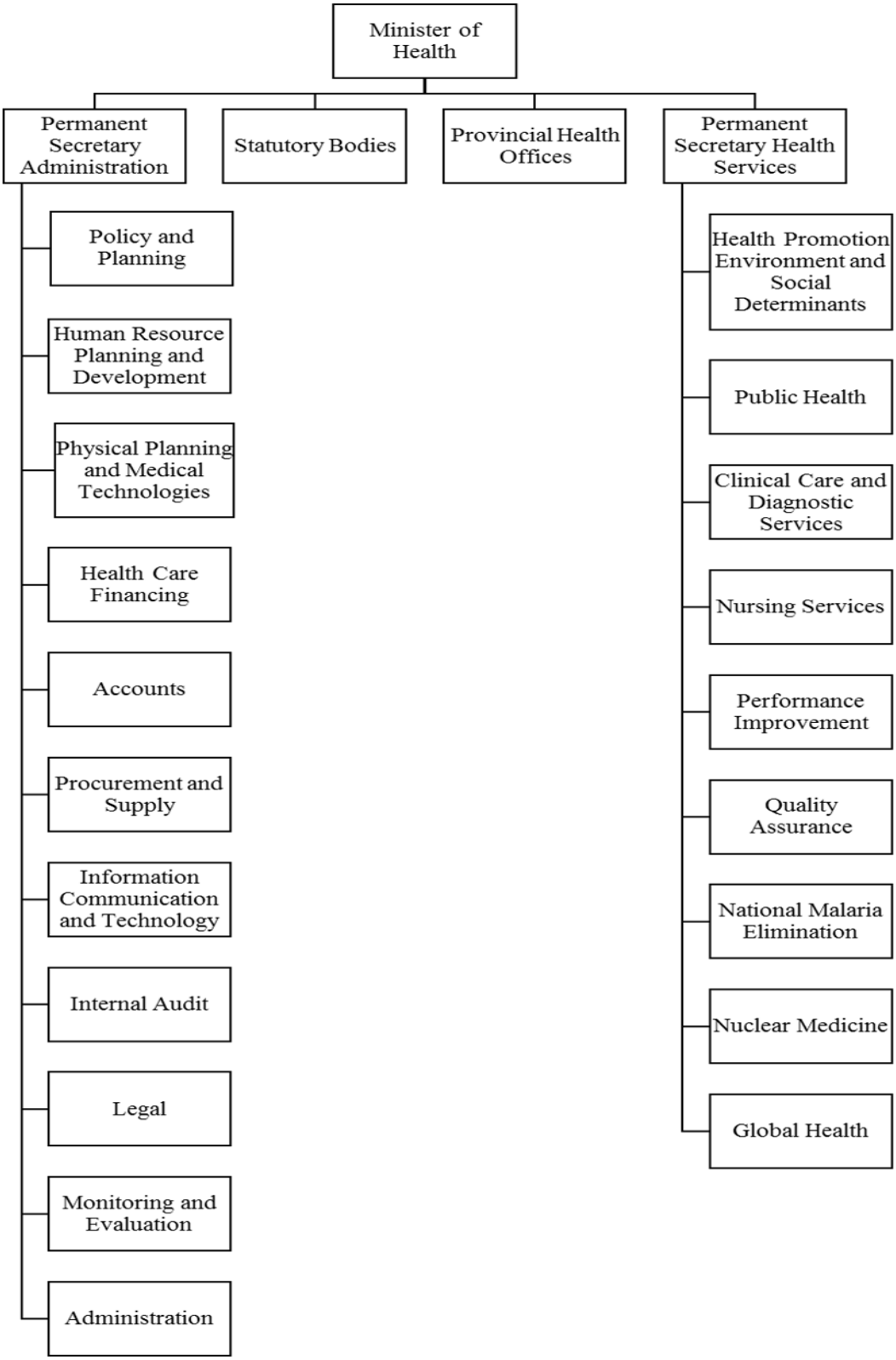


Figure 5-1 High Level Ministry of Health Structure

The Ministry has an organogram, clearly highlighting which department reports to which PS. These are key departments that can play a critical role in the control and elimination of NTDs.

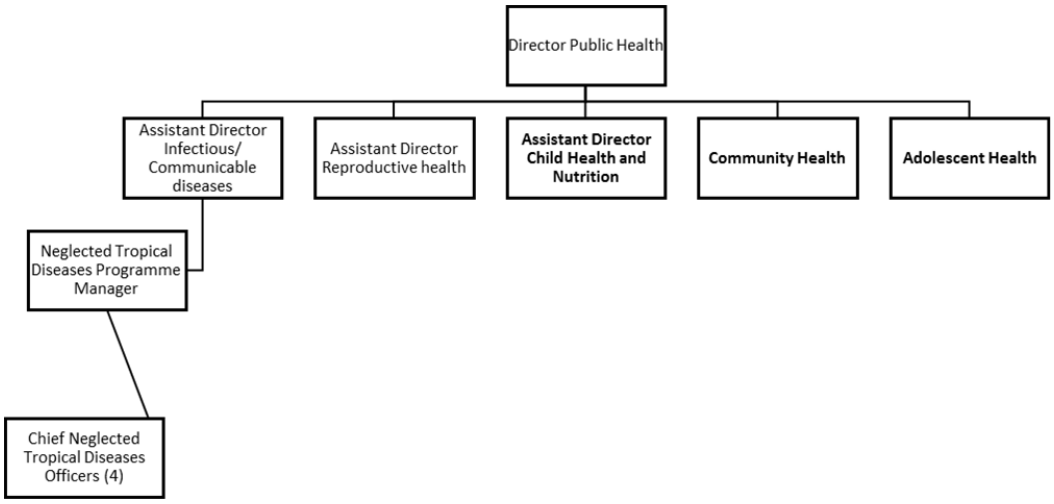


Figure 5-2 Public Health Department showing the NTD Unit

The NTD unit fall under communicable diseases in the department of Public Health.

At the end of 2016, the country had eight level-three hospitals, 34 level-two hospitals, 99 level-one hospitals, 1,839 health centers, and 953 health posts as indicated in Table 5-1. All level-three hospitals are Government owned while 26 of the level-two hospitals are Government-owned, and eight are owned by the Churches Health Associations of Zambia (CHAZ). The Ministry has embarked on increasing the number of health centres and health posts to meet the recommended 5-kilometer radius accessibility and availability of the health services in the country. Apart from the government owned facilities which carter for more than 90% of the national population, other health services are available at faith- based (not-for-profit) providers, the mines, and private (for-profit) providers (GRZ, 2017).

Table 5-1Type and number of health facilities in Zambia, 2016

Type of health facility	Total Number in 2016
Level three Hospital	8
Level two Hospital	34
Level one Hospital	99
Health Centres	1839
Health Posts	953

In 2016, 2933 health facilities were reported across the country. These can be used to monitor MDAs within their catchment areas.

Health services such as health promotion, preventive, curative, and rehabilitative services are implemented and coordinated by the district health office. Each district has a district hospital, which provides level one referral services. Below the district there are health centers, which provide both static and outreach services. A minimum of three officers manage the health facilities. These are a clinical officer, midwife or nurse, and environmental officer. The main activities at health centre level are predominantly health promotion and disease prevention under DPH and DHPESD. There are some limited curative services provided, too, with complicated cases being referred to level one district hospitals and subsequently to levels two and three as need arises.

Efforts have been made to enhance information to guide planning and decision making at district and hospital levels countrywide. This has been extended to the community level through the introduction of community health information systems. In Zambia, NTD data is obtained through the mainstream DHIS2 for those seeking medical attention at the health facilities and supplemented through MDA campaign reports. The Ministry of Health has developed a costed five-year strategic plan 2016-2021 (Ministry of Health, 2016) and every year the ministry develops annual work plans that are drawn from the five-year strategic plan. The Government allocation to the health sector in nominal terms has been increasing even though the share of the health sector budget to national budget has generally been decreasing over the past five years as shown in Figure 5-3. The overall government funding from

2011 to 2020 is 9.35 % with the highest proportion recorded in 2013 at 11.3 % while the lowest was in 2016 at 8.3 % (Government of the Republic of Zambia, 2020, Government of the Republic of Zambia GRZ, 2018, Government of the Republic of Zambia, 2017a).

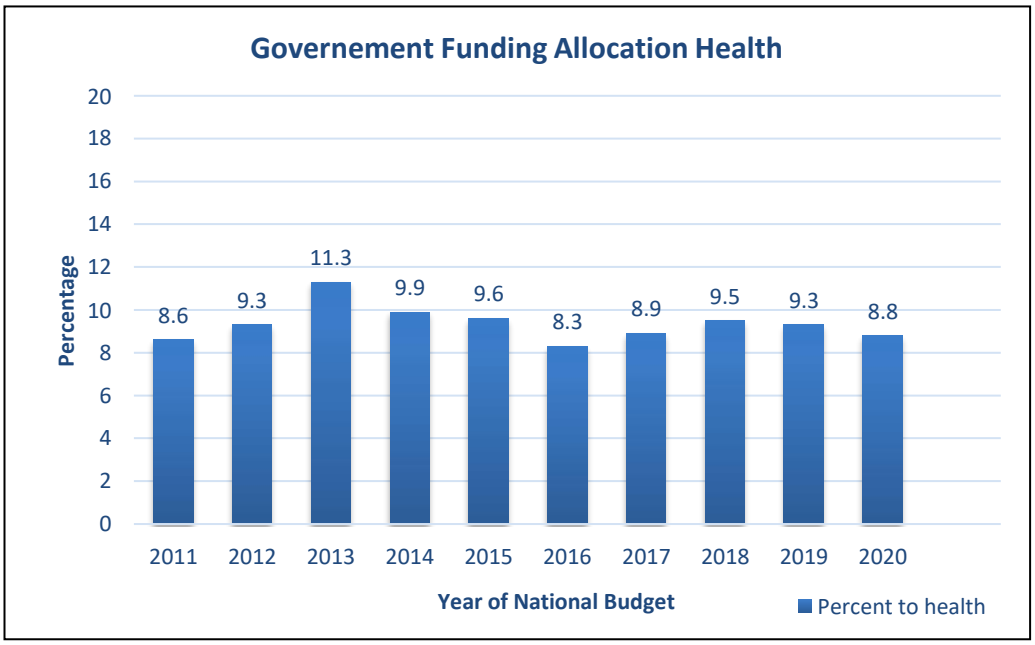


Figure 5-3 Government budget allocation to the Ministry of Health over a period of ten years.

The budget allocation to the Ministry is still below 15% according to the Abuja Declaration. The highest it reached was 11.3% in 2012 (Government of the Republic of Zambia, 2017a)

The total cost of the NHSP for all five years is estimated at US$14.3 billion (ZMK 139.8 billion). The priority areas that are major cost drivers are human resource for health US$3.2 billion (22.6% of the estimated total); infrastructure US$2.4 billion (17.1% of the estimated total); pharmaceuticals and supply chain management (essential drugs, commodities, and supplies) US$2.2 (15.8% of the estimated total); HIV/AIDS US$ 1.0 billion (7% of the estimated total); and malaria US$0.9 billion (6.5% of the estimated total). NTD has an estimated is $119 million (0.8%) of the total cost (Government of the Republic of Zambia, 2017a, Ministry of Health, 2016) but mainly donor funded

The health sector indicators are monitored through a sector-wide approach by policy meetings, the technical working groups, sector advisory group and annual

consultative meetings. The implementation of strategic plans is monitoredthroughout its implementation and evaluated at mid-term and the end of the durationof the plan.

5.6.2 Part 2 Comparison between WHO NTD Roadmap and Zambia National Plan

The comparison between the WHO recommended five strategies for the control and elimination of the three NTDs against their implementation in Zambia, shown in Table 5-2, indicates that WHO has guidelines for preventive chemotherapy for all 3 NTDs but Zambia has fully implemented for LF and started the implementation for SCH and STH. WHO has provided guidelines on intensified case detection and case management and integrated vector management for LF but no implementation has been undertaken in Zambia. Apart from the recommended treatment strategy for schistosomiasis, WHO has no guidelines on intensified case detection and case management for SCH. The veterinary public health interface does not apply to the three PC NTDs therefore not implemented for these specific NTDs. WASH guidelines have been developed by the WHO but these are partially implemented by Zambia. Overall, only preventive chemotherapy for LF is fully implemented in Zambia.

In Table 5-3, the African Regional plan of action recommends preventive chemotherapy for all three NTDs with additional morbidity management and disability prevention for LF. Zambia has implemented preventive chemotherapy but not morbidity management and disability prevention. Preventive chemotherapy for SCH and STH is partially implemented. The targets in the global roadmap are based on the on the recommendations made by Member States during the World Health Assembly on the elimination of LF (World Health Organization, 1997b) control of SCH and STH (World Health Organization, 2001) and elimination of SCH (World Health Organization, 2012c). Table 5-4 shows the progress made towards attainment of the targets. Zambia has made tremendous progress on the global target for the elimination of LF but not the control of STH and STH. The regional target for elimination of SCH in selected countries in Africa by 2020 is far from being reached for Zambia and whether the African Regional NTD Plan to eliminate SCH by 2025 will be reached, is yet to be assessed. The 75% deworming coverage for STH and SCH by 2020 has not been met by the country.

Table 5-2 Comparison of the WHO Recommended Strategies with Zambia NTD Roadmap

Key interventions Guidelines	NTDs	Global Roadmap	Zambia NTD Roadmap
Preventive chemotherapy	LF	4	4
	SCH	4	2
	STH	4	3
Intensified case-detection and case management	LF	4	1
	SCH	1	1
	STH	1	1
Integrated Vector and intermediate host control	LF	4	3
	SCH	4	1
	STH	5	5
Veterinary public health at the human-animal interface	LF	5	5
	SCH	5	5
	STH	5	5
WASH interventions	LF	5	5
	SCH	4	2
	STH	4	2

Key: 1=emergent (nothing is being done); 2=developing (starting/commencement); 3=satisfactory (partial); 4=strong (full implementation); 5=not applicable

The Table has columns comparing the available guidelines from WHO on control, elimination, and eradication for NTDs and what has been achieved in Zambia. Zambia must intensify its interventions on early case detection and management, integrated vector management

Table 5-3 WHO Recommended primary interventions for LF, SCH and STH

Disease	Interventions	Global Roadmap Guidelines	Zambia NTD Roadmap Implementation
LF	Preventive chemotherapy	4	4
	morbidity management and disability prevention	4	1
SCH	Preventive chemotherapy	4	2
STH	Soil-transmitted helminthiasis (STH) Preventive chemotherapy	4	2

Key: 1=emergent (nothing is being done); 2=developing (starting/commencement); 3=satisfactory (partial); 4=strong (full implementation); 5=not applicable

The Table shows the how much preventive chemotherapy has been implemented in the country for the three PC NTDs. Zambia is not performing well on morbidity management which is yet to be established and scaled up.

Table 5-4 Progress to WHO Global and AFRO Targets and milestones for LF, SCH and STH.

Disease	Global Target in the NTD Global Roadmap 2012-2020	Zambia NTD Roadmap Implementation
LF	Global Elimination of LF by 2020	4
SCH	Elimination of schistosomiasis in selected African countries by 2020	2
STH	75% of preschool and school-aged children in need of treatment (intestinal worms) are regularly treated are regularly treated 100% of countries have a plan of action	3
Disease	**Targets African Regional Action Plan 2012-2020**	**Zambia NTD Roadmap Implementation**
LF	Elimination of LF by 2020	4
SCH	Elimination of schistosomiasis by 2025	2
STH	Deworming coverage of 75% of preschool and school-aged children at risk of STH by 2020	2

Key: 1=emergent (nothing is being done); 2=developing (starting/commencement); 3=satisfactory (partial); 4=strong (full implementation); 5=not applicable

The Table shows the progress made towards attaining the global and regional targets for the three PC NTDs. Zambia has not been able to reach the global and regional targets but has commenced the implementation of interventions

The indicators in the Joint Reporting Form for preventive chemotherapy NTDs show that the endemicity status of all the implementation units are fully known for the three NTDs as indicated in Table 5-5. The planned interventions and the estimates of the population requiring treatment are fully known. However, the number of people that received treatment at least once in 2017 was more than 75% but less than 100% for LF, moderate for STH above 50% but less than 75% and very low for SCH below 50% giving LF high coverage compared to SCH and STH. The inventory for the donated medicines is very low especially for SCH and STH medicines even the provision of medicines in stock in the JRSM is low for SCH and STH. However, the report on the quantities in stock, in the pipeline, what is required for the following year and what is being requested is high above 75%. The number of people requiring treatment and the dates are usually planned for and are available for all the three NTDs at over 75%. No information is known about other medicines that are donated by partners apart from those coming from WHO. The indicators in the EPIRF show that there is 100% epidemiological data for the three NTDsnecessary to complete the form.

Table 5-5 WHO Joint Application Package for LF, SCH and STH

In terms of preventive chemotherapy, Zambia's performance in SCH interventions is very low. LF programme on preventive chemotherapy has above average while STH is trailing behind

Form name	Indicator	LF	SCH	STH
JRF	Endemicity status of the implementation unit	4	4	4
	Planned interventions	4	4	4
	Population requiring treatment by age group	4	4	4
	Number of people received treatment at least once in that year for the disease	**4**	2	**3**
	The coverage for PC interventions for the diseases both geographical and national	4	2	3
	Number of people treated and programme coverage (and therapeutic coverage) by PC interventions	4	2	3
	Inventory of PC medicines with medicines accounted for	4	4	4
JRSM	Information about the PC medicines requested from HQ, in stock, in pipeline and requested	4	3	3
	Number of people to be treated with the donated medicines	4	4	4
	Dates of the planned MDAs rounds for the three NTDs.	4	4	4
	Information of medicines requested for MDAs not donated by WHO	1	1	1
EPIRF	Indicators on the epidemiological data on LF and the morbidity management and disability prevention	2	5	5
	Indicators to report epidemiological data on SCH species specific and intensity.	5	3	5
	Indicators to report epidemiological data on STH and SCH including the species specific and intensity.	5	5	3

Key: 1=emergent (nothing is being done); 2=developing (starting/commencement); 3=satisfactory (partial); 4=strong (full implementation); 5=not applicable

The comparison between 24 WHO NTD tools and guidelines against their implementation in Zambia Table 5-6 indicate that despite availability, Zambia only implemented four fully while 5 are partially implemented, 11are starting and6 are emergent. The four fully implemented include national plans, epidemiological data, joint requests for PC Medicines and estimated number of people requiring preventive chemotherapy for lymphatic filariasis. The focus areas that are doing badly include integrated vector and intermediate host management, WASH to combat NTDs, effective NTD coordination and intensified disease management, effective vector,

NTD coordination mechanism and progress towards the elimination of schistosomiasis. No programme is being implemented on morbidity management and disability prevention. Real time data is not available but the data that is received is reliable. High coverage is not sustained of the MDA and operational research is emergent.

Table 5-6 Comparison of key indicators of resources for effective implementation for the NTD Roadmap

Indicator		Zambia NTD implementation
WHO Elimination Targets for NTDs		**3**
A Master Plan for National NTD Programmes		4
Financial estimate costs for country and donors		3
A Roadmap for implementation to accelerate working to overcome the Global impact of NTDs		2
NTD Mapping Plan to determine Disease burden, distribution, and epidemiological data		4
Joint Request for Preventive Chemotherapy NTDs Medicines (Estimated number of people requiring treatment)		4
Essential Medicines Donated to control and eliminate NTDs		3
Integrated Vector Control Guidelines		1
WASH to combat NTDs guidelines		1
Effective NTD Coordination Mechanism		2
Training Modules for PC NTDs		2
Access of interventions for all populations		2
Programme to Eliminate LF		3
Preventive chemotherapy in human helminthiasis	LF	4
	STH	2
	SCH	2
Morbidity management and disability prevention		1
Effective integrated Vector and intermediate host management guidelines		1
Health awareness and education		2
Validation Tools for Elimination		2
Monitoring and epidemiological assessment of MDAs		3
Integrated NTD Database (CIND)		2
Real-time accurate monitoring		1
Data management systems closely coordinated		2
Opportunities for elimination through sustained high coverage		2
Research Priorities for helminth infections		1

Key: 1=emergent (nothing is being done); 2=developing (starting/commencement); 3=satisfactory (partial); 4=strong (full implementation); 5=not applicable

The comparison of the implementation of the building blocks in Table 5-7 indicated that the global roadmap has provided clear guidance on the implementation of all the six building blocks of health system strengthening. The NTD roadmap has implemented 3 of them fully while the remaining three are partially implemented. The three fully implemented include delivery of safe quality assured intervention both at community and individual levels, health workforce mix that is responsible and effective with minimum resource wastage and the equitable access to medicines which is efficacious and cost-effective. Most of the NTD drugs are donated for mass drug treatments. Partially implemented blocks include information systems which has reliable content but is not timely, domestic funding for NTDs is still inadequate and mainly donor-dependent while leadership and governance of the NTD programme is not fully implemented however, the National NTD Master Plan, which is a strategic document for NTDs has been developed. The coalition building, regulations, and attention to system design in line with the NTD programme is partially implemented. The National Health Policy and National Health Strategic plan 2016-2021 have a component of NTDs.

Table 5-7 Building block for health system strengthening.

The general implementation of the building blocks of the health system strengthening is doing fine. However, Information management, health care financing and regulations and attention to system design in relation to NTDs is still partially implemented.

Building block for health system strengthening	Focus area	Global roadmap	Zambia NTD Roadmap
Delivery of safe quality assured interventions	Individual level	4	4
	Community level	4	4
Health workforce that is responsible and effective	Health Worker mix	4	4
	Minimum resource wastage	4	4
Information systems	timely	4	3
	Reliable	4	4
Equitable access to medicines	Safe and efficacious	4	4
	Cost effectiveness	4	4
Health financing system	Domestic funding	4	2
	Funding partners	4	4
Leadership and governance	Strategic policy framework	4	4
	Coalition building	4	3
	Regulation	4	2
	Attention to system design	4	2

Key: 1=emergent (nothing is being done); 2=developing (starting/commencement); 3=satisfactory (partial); 4=strong (full implementation); 5=not applicable

5.6.3 Part 3 The influencers of the NTD Health Policies and review the key actors driving the process of the Zambia NTD programme

A review of 15 key partners that have supported the NTD programme in countries highlighted in Table 5-8 indicates that some despite being present in Zambia, most of them do not provide financial or technical support to the NTD programme. Out of the 15 partners 46.7% have supported NTDs and these include Centre for Neglected Tropical Diseases (CNTD), sight savers, Schistosomiasis Control Initiative (SCI), Expanded Special Programme for the Elimination of NTDs (ESPEN), WHO and several pharmaceutical companies for the medicines donated to Zambia through WHO. However, partners like CNTD and SCI have been replaced by Accelerating the Sustainable Control and Elimination of Neglected Tropical Diseases (ASCEND).

The NTD programme areas that are receiving support from these partners are the one that are making progress. In this instance, the constant support from CNTD and LSTM towards LF elimination has seen the LF programme move faster than the other two NTDs. The line ministries are key stakeholders but only one (Ministry of Education) works with MoH on the NTD programme. Other ministries like Ministry of Traditional Affairs, Ministry of Religious and National Guidance and Ministry of water and sanitation, though have a critical role for the effective implementation of NTD interventions do not align well with the MoH NTD programme.

In addition to the external and internal organisational and institutional influencers of the NTD programmes, additional internal and external influencers at a programmatic level were also identified and presented in Figure 5-4. The internal influencers include ownership of the programme by the government and using a multisectoral approach in addressing the local contributing risk factors to NTDs, local factors including recognition of the disease as a public health problem and establishment of a national programme that can plan and coordinate NTD activities. External influencers identified are Donors or funders of the NTD programme, the NGOs and civil societies and the pharmaceutical companies that manufacture and donate medicines required for mass drug administration.

Table 5-8 NTD Partners and stakeholders that normally work and support NTDs both national and international levels with their possible contribution

Known Funding and or implementing Partners that support NTDs	Present in Zambia	Support to NTDs	Support towards elimination of the three NTDs in Zambia
World Bank	Yes	No	Financial Support to scale-up interventions
Department for International Development	Yes	No	Financial Support to scale-up interventions
End Fund	Yes	No	Financial support and implementation
Bill and Melinda Gates Foundation	No	No	Financial support
Centre for Neglected Tropical Diseases	No	Yes	Support the LF programme
Schistosomiasis Control Initiative	No	Yes	Have not reached all the districts
Pharmaceutical (Esai, Merck, Johnson and Johnson, GSK)	No	Yes	Not directly to Zambia but through the donated drugs
ASCEND	Yes	Yes	Just coming on board
ESPEN	No	Yes	Support PC NTDs strategies and activities
WHO	Yes	Yes	Technical and Financial Support
Sight savers	Yes	Yes	Trachoma in selected districts
World vision	Yes	No	
China Government	Yes	No	
JICA	Yes	No	
Ministry of Agriculture	Yes	No	No collaboration
Ministry of Local Government	Yes	No	No collaboration
Ministry of education	Yes	Yes	Yes, through MDAs for STH and SCH. Collaboration to expand
Ministry of Higher Education	Yes	No	No collaboration
Ministry of religious and National Guidance	Yes	No	No collaboration but key for social mobilisation
Ministry of Traditional Affairs	Yes	No	No collaboration but key for social mobilisation and village and community level
Ministry of Water and Sanitation	Yes	No	No collaboration but key in WASH for targeted interventions
Ministry of Health (Structures at lower levels)	Yes	Yes	Provincial, district, health centre and health posts for implementation
Community Health Workers	Yes	Yes	To support community interventions. Ministry of Health has a unit responsible for community health

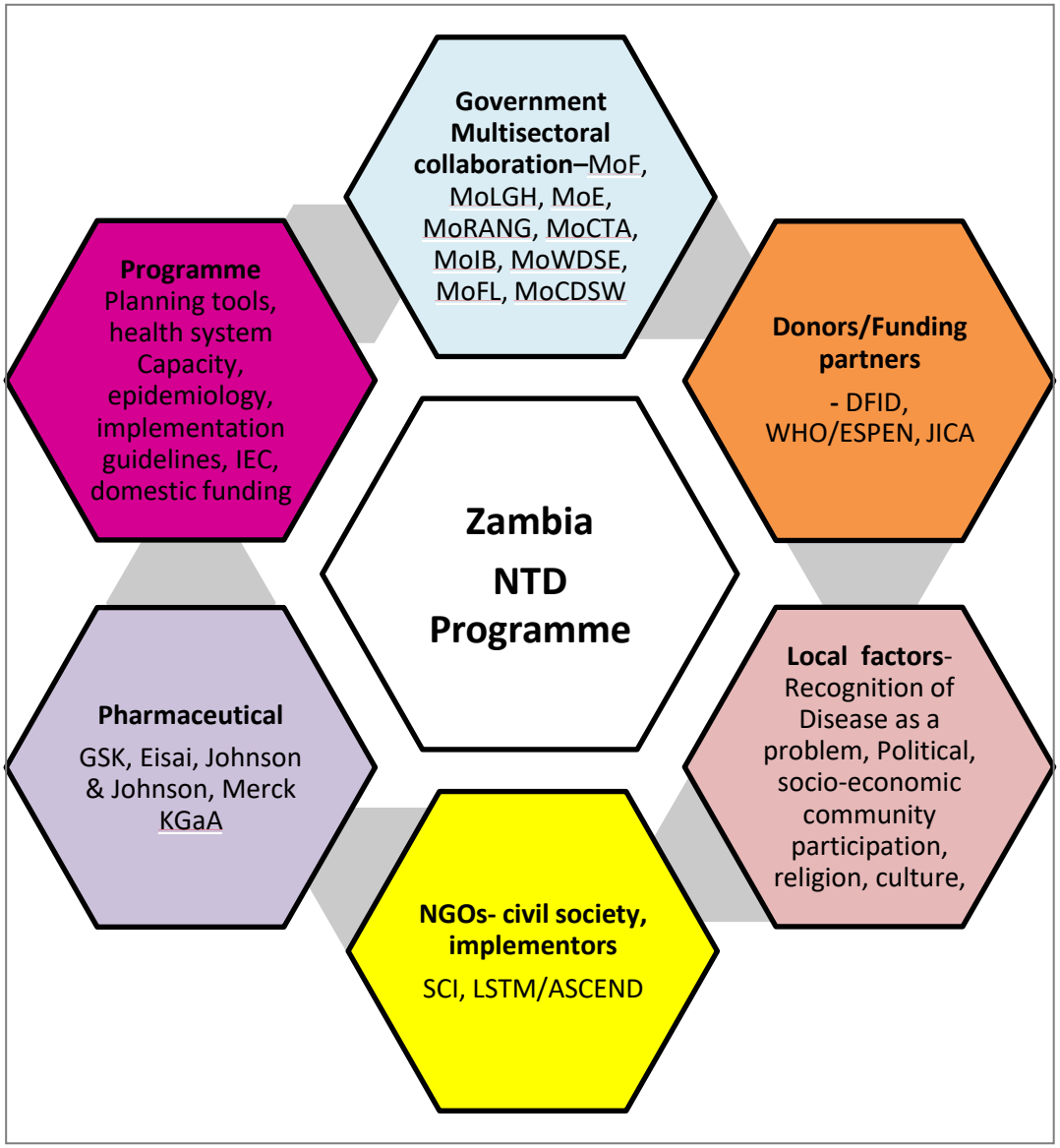


Figure 5-4 Internal and external influencers a programme implementation level

The main identified internal influencers include tools, human resources and capacity, epidemiological data, domestic funding while the donors and pronouncements by WHO are the main external influencers

5.6.4 Part 4 Policy gaps and solutions in the delivery and coverage of interventions for LF, STH and SCH

Figure 5-5 highlights some of the policy gaps of the NTD programme in Zambia and is a combination of the possible factors leading to the policy gaps impacting on the success of the NTD programme and some of the solutions or interventions needed to address them. The main factors that have been identified include inadequate funding to the NTD programme, inadequate knowledge of NTDs, challenges medical supply management and poor programme coordination and implementation of interventions such as preventive chemotherapy and lack of vector control. Other factors include traditional, cultural, and religious misconceptions of NTD in communities. The interventions applicable to the Zambian settings to address these factors one by one include resource mobilisation to increase donor and domestic funding, build capacity of NTD staff, improve on the drug supply management and scale up interventions such as preventive chemotherapy and integrated vector and intermediate host management. Other interventions are mobilised and engage communities, improvement on the coordination mechanisms at all levels and to monitor and evaluate the programme and ensuring quality assurance and performance improvement.

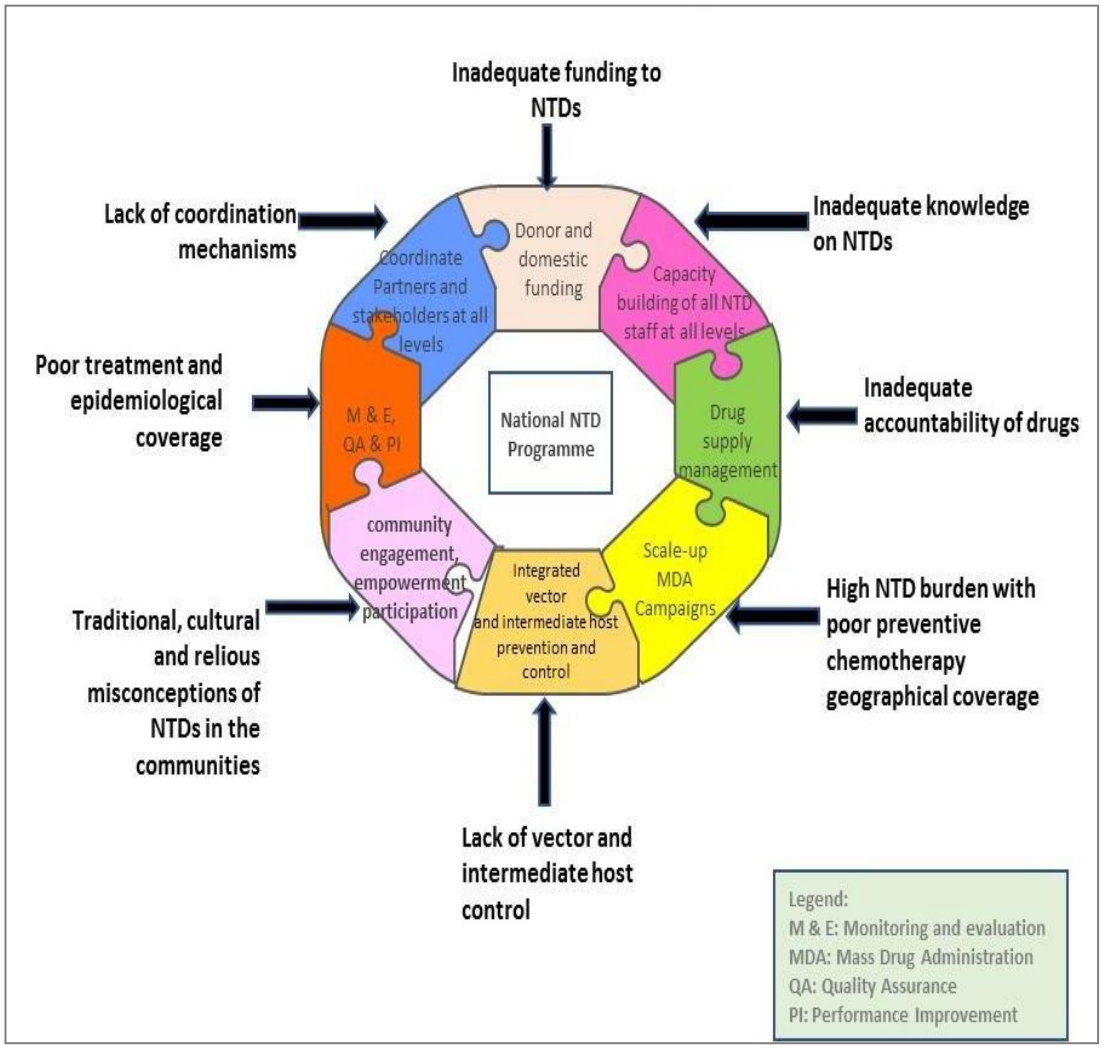


Figure 5-5Determinants of the success of the NTD Programme in Zambia

8 major gaps and issues identified are outside the ring including the high NTD burden with poor preventive chemotherapy geographical coverage, while the solutions are in the middle such as such as scale up MDA campaigns. These contribute to the success or failure of the National NTD Programme

5.7 Discussion

5.7.1 Infrastructures and access points within the Zambian health system

The chapter on policy analysis brings a new dimension to long-term thinking about the future approach for NTDs in Zambia by highlighting strengths, weakness, opportunities, and the solutions to challenges. In doing so, it gives a boost to drive prevention, control, and elimination of the three NTDs. However, the drive to sustainable results requires environmental improvements, increased vector control, and WASH interventions in a value-added way with the strong commitment from the MoH, other sectors and partner investments in NTDs. These influencers are crucial to reaching the roadmap targets by ending catastrophic health expenditures and, as part of the drive to strengthen health systems, in getting services closer to where people live.

The health service delivery system mirrors the political administrative structure from the central level to the district levels. The PHO is the link between the national and district level and is charged with backstopping provincial and district health services. The province is tasked with the provision of second-level referral services (through general hospitals). The Provincial Medical Office, second- and third-level hospitals and central hospitals, DHOs, and training schools receive funds directly from Ministry of Finance (MOF). These structures are key for the health service delivery up to the lowest level. Therefore, the government's plan to decentralize the health system will help develop the local lower levels. The MoH central level should continue with policy formulation and guidance; monitoring and evaluation; and donor coordination. Decentralization of planning, and finance management improves some health indicators as it involves regional and district levels of the health system (Mensah et al., 2016, Ramos et al., 2020). It would be worthwhile if the district continued to provide technical guidance on the quality of care, planning, health facility management, good governance, human resources, rational use of drugs and administrative supervision of the health facilities in Zambia. The districts should also strengthen data collection which they should share with the higher levels of the health system. This will help with the NTD programme especially the preventive chemotherapy, vector and intermediate host management and morbidity management and disability prevention because these will be planned for

and implemented by the district and the sub-district levels that know the extent of the problem and where specific interventions should be applied.

Human resources for health are critical for the provision of health services including the control and elimination of NTDs. In this regard the MOH's planned recruitment of over 30,000 health workers and training of community health workers according to the current NHSP will improve the health worker patient ratio. MoH recruited NTD officers to enhance the implementation of NTD activities. However, the officers require capacity building on NTDs. The construction of health facilities to meet the 5 km radii and the continued recruitment of the health workers to be positioned in rural areas will help in screening and management of patients with NTDs as the services are being brought where the people live. Monitoring of school and community-based interventions for NTDs will be enhanced because these will be within a catchment area of a health facility. This is supported by the increased health facilities that have been constructed that will have health workers to ensure medicines for PC and implementation of activities are well structured. In addition, at the national level, the various departments in the MoH if coordinated properly can facilitate in addressing the NTDs.

The Ministry of Health should embark on the attainment of Universal Health Coverage which is crucial for NTD control and elimination. This will help in sustaining gains achieved by ensuring that needed health services reach all people, particularly the underserved populations. The Sustainable Development Goals now present opportunities to accelerate progress on NTDs through the implementation of multisectoral interventions, such as improvements in water and sanitation, food safety, environmental health and veterinary public health which are solely under the jurisdiction of other departments (Mabey et al., 2021). Joint planning, resourcing and delivery of these interventions must be prioritised to accelerate progress (World Health Organization, 2015). Therefore, in line with the National Health Strategic Plan 2017- 2021 (Ministry of Health, 2016) which focuses on primary health care and community health approaches and taking into consideration the magnitude and impact of the burden of NTDs prevention, control and elimination of NTDs should be prioritised at all cost. Since NTDs are amenable to broad control, elimination or eradication by delivering one or more of the five interventions recommended by

WHO in Table 5-2, including preventive chemotherapy; veterinary public health; provision of safe water, sanitation and hygiene; vector and intermediate host control; and case management and rehabilitation), study has shown weaknesses in most of these and the focus should intensify campaigns. The integration of the intervention will accelerate the elimination of NTDs. Although support from some donors continues, for sustainability purposes, domestic funding should be enhanced especially when implementing integrated interventions as donors usually would support or focus on one specific entity.

The ministry has a department designated for promoting health and a unit that enhances engagement with the communities. The department would play a cardinal role in health education and behavioural change communication for the prevention, control, and elimination of NTDs which at present is not fully implemented and is not a priority. The strategies in the NHSP have high impact interventions that aim to speed up the achievement of the SDGs and UHC with a focus on the PHC. The outcomes and targets of the roadmap for NTDs in Zambia should be strengthened by streamlining the NTDs in the National Health Strategic Plan 2016-2021, National Health Policy, with reference to the Global NTD Roadmap and Regional NTD Action Plan. MOH should work towards advocating for increased funding to the health sector as a signatory to the Abuja declaration target of 15% of the national budget (African Union, 2001) to increase the domestic financing of the primary health care interventions for health promotion. The health care financing department should support the alleviation of the poor communities by providing at least 80 % essential health service coverage and financial protection from out of pocket spending of 100% in the rural parts of the country.

5.7.2 Focus on policy gaps for LF, STH and SCH

The shortfalls identified by the study need urgent attention. Currently, there are no nationwide MDA campaigns for SCH and STH being implemented, but LF MDAs have been going on since 2012/13 and have already reached the fifth round in one province. The five rounds for the remaining other provinces will be attained in 2020. These MDAs are community based which is in line with the NHSP and CDTi used by the African Programme for Onchocerciasis (World Health Organization, 2002) which was highly funded by CNTD. This has led to one NTD being controlled and

reaching elimination levels. There is no integration of interventions starting from national level downwards. The control programme must be strengthened by capacity building with clear responsibilities to conduct a situation analysis, strategic planning, budgeting, and timely distribution of medicines which is closely supervised and monitored. The drug distributers and social mobilisers do not integrate activities and when that is done, they request for additional funds as that is the notion that additional incentives are required. The interventions are being implemented with variable intensity hence the status. The WHO joint package for preventive chemotherapy NTDs should be used to facilitate integration, through applying for preventive chemotherapy medicines and for reviewing and reporting national epidemiological data, as well as to improve coordination and integration among different programmes (World Health Organization, 2015). To maximize impact of increasing partnerships and resources dedicated to NTD control, I suggest four programme organizational strategies that include coordination of partner activities at international, national and subnational levels, integration of programme with similar delivery strategies on the same platform, the integration of programmes into the public health system to improve coverage; and to promote collaboration between NTD programmes and other public health interventions with better funding and structures at the implementation unit to strengthen the public health system for the benefit of all (Mensah et al., 2016). Integration of NTD programme activities into health system structures is an option relatively within the control of country NTD programmes and hence its quick implemented should be encouraged. The support for NTDs ought to encourage integration right from the start and Zambia must address this concern with the partners supporting siloed interventions and should take ownership, stimulate demand, and implement the national plans.

The study also identified the non-availability of guidelines on management of SCH morbidity in highly endemic areas were the communities have developed the different stages of mild to severe or irreversible complications. Guidelines are there for LF morbidity management and disability prevention (World Health Organization, 2013b) which provides the principles of primary health care and community health. The NHSP has added a few recommendations with emphasis on the critical role of primary health care for everyone everywhere to attain the highest possible health care in line with the Alma Ata Declaration of 1978 (World Health Organization, 1978),

SDGs and UHC which is sustainable and to which Zambia committed to. Despite the guidelines being available for LF morbidity management, implementation of these guidelines are not fully implemented which should be strengthened in the country. However, the recommendation to WHO for SCH is the development of the morbidity management guidelines. The primary health care providers and the community health workers do not focus on NTDs as they have inadequate knowledge and skills on the morbidity management. This guidance is required for the NTD unit staff including the referral standard operating guidelines provided in an algorithm.

The coordination of the NTD programme is weak at the national and non-existent in most areas at subnational levels. Moreover, some critical interventions go beyond the scope of health requiring intersectoral coordination and collaboration. This needs to be addressed by developing a coordination mechanism or structure for all the levels from community to national level with clear terms of reference for each level which currently is lacking. This approach will require a lot of support from all key stakeholders, implementing partners and sectors so that together they can work more effectively and efficiently. A lot of advocacy on the benefits of coordination and collaboration for a deliberative action is relevant. Lessons can be learnt from the successful implement of a coordination mechanism in Nigeria which led to enhanced collaboration, reduction in duplication of efforts and increased partner reporting on activities implemented (Igbe, 2017).

Further, the intra-MoH coordination and collaboration is missing despite the various departments that can contribute tremendously and are critical to the NTD programme. The MoH has a unit responsible for the NTD programme under the Department of Public Health (Figure 5-2) with five staff assigned to it namely NTD Manager and four Chief NTD Officers. There are also other departments (Figure 5-1) that can support the unit like the department of Health Promotion Environment and Social Determinants (HPESD), Department of Quality Assurance, Department of Performance Improvement, Department of Policy, Department of Planning and Budgeting, Department of Monitoring and Evaluation. Within the Department of Public Health is a Community Health Unit. All these are important to the successful implementation of the NTD programme, but the unit is not engaging for support. NTD data management is equally very poor, and it takes a very long time to report

on any activities conducted at sub national levels. The ministry has a monitoring and evaluation unit, information, communication, and technology unit but these are not being utilised to the benefit of the programme. During MDAs it takes more than a month to get reports from the implementing units on the numbers treated and coverage. Doing an inventory on the medicines sometimes becomes a challenge. There is no dedicated NTD data manager or logistician for drug supply and management, to address the data issues. Staffing levels even though it as improved from one person in the unit to five technical staff, key areas like data management, health promotion and logistics require assignment or secondment to the NTD programme from the relevant departments within the MoH.

Intensified disease management not done as the MMDP component of the programme is yet to scale up which will require mapping cases with morbidity and planning outreach activities. To date, the programme has only focussed on MDA to interrupt transmission and prevent more people suffering the debilitating consequences of lymphatic filariasis. In Zambia, some efforts to coordinate partners implementing NTDs was initiated by Sight Savers but this has implications on the ownership (Engels and Zhou, 2020) of the programme a weakness that the MoH has to quickly address.

WHO, has provided guidelines on the treatment strategies, target populations for PC NTDs and the focus of the NTD programmes in countries in order to control and eliminate NTDs. The three NTDs of my study have different treatment strategies, while LF interventions focuses on entire population, STH and SCH are limited to SAC leaving out the pre-SAC and adult populations that are treated either by other partners or on different platforms such as under-five clinics and antenatal clinics. The NTD programme only provides medicines for the SAC even though the other age groups are identified to be at high risk of infection but are not receiving treatmentas part of the NTD programme (Engels and Zhou, 2020). One other oversight by the pharmaceutical companies donating medicines and by the ministry is the non-availability of albendazole, praziquantel and diethylcarbamazine focused on treatment of patients visiting the health facilities outside the MDA campaigns for routine use. Even though the medicines are now in the national formulary and should be part of routine procurement and included in the health centre kits.

5.7.3 A way forward for improvement

It is very clear from the study findings that if the 2020 targets and beyond are to be met, the universal health coverage gap for NTDs should be closed. A way forward for improvement is to expand from poverty alleviation to shared prosperity which subsequently also addresses the issues on NTDs which, through responses to most SDGs have direct link and relevance to NTDs especially SDG3 on health, ending poverty (SDG1), ending hunger (SDG2), ensuring equal opportunities to education (SDG4), available management of water and sanitation (SDG6), (Nations, 2015). The MoH should also work towards ensuring that all people receive promotive, preventive, curative, rehabilitation and palliative health services they need or sufficient quality that do not expose them to financial hardship and also promote equality in service distribution (World Health Organization, 2018a). Therefore, the NTD policy or strategic plan should be comprehensively revised to highlight the national NTD goals, strategic objectives, multisectoral and multi-partner approaches, and key performance indicators for the next five years and beyond. The NTD programme and NTD master plans should be owned by the government while partners should use them as guides to support national NTD priorities. Stakeholders and partners should adhere to them and work together systematically and progressively to achieve health for all for NTDs. The policy should address the weaknesses brought out in this analysis to enhance and strengthen relevant health system building blocks for universal and equitable access to essential NTD interventions and services, particularly to reach the unreached, underserved populations. A multi-sectoral and multi-stakeholder national coordination and collaboration should be at the core of the national plan, in addition to scaling up preventive chemotherapy, integration of water, sanitation and hygiene (WASH) programmes into NTD programmes where appropriate critical at this stage (Campbell et al., 2018a, Campbell et al., 2018b). It is vital to tackle and eliminate the determinants and risk factors of NTDs.

The three NTDs are targeted for elimination and therefore requires long term commitment by the government and active collaboration with partners ad sectors. Access to clean safe water, sanitation, hygiene, and environmental manipulation will accelerate the elimination of the NTDs. Bringing all the actors on board and work together, basing interventions on available evidence, has a considerable potential to

facilitate the attainment of the national NTD goals and targets (Zhang et al., 2010, World Health Organization, 2013f, World Health Organization, 2013g). To achieve this a lot of high-level advocacy and building multisectoral partnerships with key stakeholders: ministries, national and local WASH agencies, corporates, local health groups, behaviour change, and communication experts WASH elements are crucial and should be prioritised at all levels as a key elements of the elimination and control of NTDs. The trade-off with this kind of arrangement is to start integrating LF, SCH and STH activities instead of the vertical solo programme. This will address many cross-cutting issues for sustainability (Engels and Zhou, 2020, Nations, 2015) and will be an ideal value for money. External funders should also push for this move of integrating as they are influencers with what is implemented and support programmes financially. They support provided should not instruct countries to address only one component of the strategies. This will then support integration of less funded interventions such as integrated vector and intermediate host management.

Community involvement and empowerment in the populations at risk of these NTDs including social behavioural change communication should be the country's priority in the NTD agenda which is significant for the success and sustainability of the NTD programme (Silumbwe et al., 2019, Kabatereine et al., 2014). Building capacity in the community health workers, social mobilisers, neighbourhood health committees and media bodies is very important to educate the people about the disease to stop discrimination and stigmatisation. Behavioural change communication and improvement in treatment coverage should be a focus area in the plan for the next five years. Involvement of the church, community leaders and other local influencers in social mobilisation will help to increase the coverage. Communities lacking certain services for the prevention, control, treatment and rehabilitation centres should receive more support to alleviate the suffering of many people living in rural areas affected by NTDs and ensuring the identified reasons as to why interventions are not implemented addressed.

Preventive chemotherapy should be scaled up for SCH and STH to reach 100% geographical coverage and scaled down for LF in Zambia. Treatment of SCH and STH which is limited to SAC should be revisited and ensure all the eligible

population at risk receive treatment including pre-SAC and adult who live in endemic districts to interrupt transmission. Furthermore, due to the focality of the disease, only endemic sub-district levels should be treated through mass drug administration. As a matter of urgency, Zambia should review mapping data from each implementation unit and come up with the prevalence map at sub-district level. Each implementation unit should clearly define treatment areas and the target groups.

The building of local capacity is sustainable and will ensure effective scale-up to achieve elimination targets. The services to manage morbidity in the health facilities are inadequate and, in some facilities non-existence, because there is inadequate skilled manpower. The inclusion of albendazole, praziquantel and diethylcarbamazine in the health centre kits for routine use in the management of the PC NTDs is highly recommended.

Zambia has made great strides in implementing the building blocks for health system strengthening as indicated in Table 5-7. To address the identified gaps in timely reporting of information and domestic funding, engagement with the ICT unit and M & E for timely reporting and health care financing to address the issue of domestic funding should be pursued. Efficient drug management system should be implemented.

5.8 Conclusion

To overcome the impact of NTDs in Zambia should target universal health coverage of NTDs by making NTDs which will contribute to the reduction of people suffering from NTDs. The study's identified internal and external influencers in the development and or updating of an NTD policies in Zambia should be targeted with broader investment strengthening health systems. To influence an effective NTD policy and strategy in Zambia beyond 2020, government commitment and ownership, improvement in coordination, collaboration and cooperation at all levels, and establishment of a multisectoral approach to addressing NTDs is critical. Other areas to be heightened is the micro-planning, effective behavioural change communication and improvement in treatment and geographical coverage ensuring that everyone is reached.

Although my study has generated evidence on the external and internal influencers of the NTD programme in Zambia, further research is needed to identify the potential costs for effectively implementing an NTD programme which should include the cost of coordination of a multisectoral and multi-stakeholder approaches. Operational research and lessons learnt on the roles of foreign, local donors, and community health workers in integration should be documented including the opportunity cost.

Chapter 6 Recommendation, Prospects 2030, Future Research for NTDs in Zambia

The aim of work carried out in my study is to map the distribution of LF, SCH and STH, assess the associated risk factors and determine the treatment requirements for preventive chemotherapy for an integrated NTD Elimination Programme. In accordance with other initiatives in Africa, with particular focus placed on: 1. LF transmission dynamics and potential impact of vector control (finding synergy with malaria control activities); 2. the fine-scale distributions of SCH and STH which guide future preventive chemotherapy and 3. an updated situation policy analysis for the NTD programme within Zambian health system from a within-Ministry of Health perspective.

6.1 Summary of key results

In line with the above focus, Table 6-1 outlines the key results and findings from my study.

Table 6-1 Summary Table of my key results and findings

Focus Area	key summary results
LF transmission dynamics and potential impact of vector control	National prevalence =7.4%
	56 districts endemic after mapping
	Decline in prevalence 2003-2014: 11.5% to 0.6%
	Increase in ITN coverage 2003-2014: 0.2%-76.1%
	rho correlation -0.462 significant at 0.01 level 2 tailed
	Increase in R squared with bednet from 0.1772 to 0.2837
The distribution of SCH in Zambia	National prevalence SCH=16.6%:
	69 districts endemic
	Significant hot spot and cold spot clusters at 99% confidence level;
	Significant correlation between species prevalence with environmental and climatic predictors (elevation, mean annual temperature, maximum temperature warmest and coldest months, precipitation wettest and driest months
The distribution of STH in Zambia	National prevalence STH 22.0%; 70 endemic districts; 41requiring MDA
	Significant hot spot and cold spot clusters at 99% confidence level;
	Significant correlation between species prevalence with environmental and climatic predictors (elevation, mean annual temperature, maximum temperature warmest and coldest months, precipitation wettest and driest months, and top-soil types.
Policy analysis of NTD Elimination Programme in Zambia	NTD structure in the Ministry of Health
	WHO NTD Roadmap not fully implemented in Zambia
	Recommended interventions for STH and SCH emergent, developing, partially and fully implemented, no morbidity management.
	Poor progress on the global and regional targets
	Implementation of the six building blocks of health system strengthening in relation to NTDs in Zambia
	Internal and external influencers of NTD policies identified
	Identified Policy gaps and proposed solutions

Given the paucity of the information previously available on the distribution of LF, SCH and STH in Zambia my study has brought to light salient findings that will now provide valuable information to support plan for integration of interventions and elimination of NTDs in Zambia. My study findings have produced evidence that has been used to better determined the populational estimates of the disease risk as based on in-depth field surveillance and associated prevalence data. Using these disease maps, I was able to identify focality within and between districts which denoted hot spot or cold spot clusters of disease, often associated with several environmental predictors. Explicit demonstration of hot spot clusters allows the programme to not only better target resources geographically but also intensify intervention measures

at these sites through time. However, to do so requires some realignment of current NTD guidelines and better community dialogue within-districts to reassure those that do not treatment versus those that are due to receive more. Nonetheless, in this resource constraint situation in Zambia it could offer better value for money against disease impact targets.

6.2 Why expanded LF, STH and SCH are needed

Zambia has missed previous set goals and targets on control and elimination of LF, SCH and STH and now is the time to move the national NTD agenda forward. With more than 50% of the Zambian population at risk of NTDs, based on my study findings, accelerating the milestones by scaling up interventions to national levels for the three NTDs must be Zambia's goal. The SDGs have included NTDs under SDG3 with an indicator of "number of people requiring interventions against neglected tropical diseases" (Nations, 2015). Zambia has to better track reductions in this indicator by mainstreaming the NTD programme within the broader UHC agenda.

In terms of current and future integration of control interventions, LF, SCH and STH have several cross-cutting interventions which could be addressed collectively and by so doing will accelerate the implementation of otherwise siloed activities. The implementation of activities related to advocacy, mobilisation of resources, health education across sectors and communities, MDA for preventive chemotherapy using various delivery channels, morbidity management through activation of primary, secondary or tertiary health structures, monitoring and surveillance for treatment coverage and disease forecasting alongside general health impact assessments of populational biometric indicators, ought to be aligned on shared platforms with the hope of streamlining within the health system and improved cost effectiveness. These will increase sustainability and direct towards improved geographic, epidemiological, treatment and universal health coverage with strengthened community involvement and community engagement. These will be the cornerstone of the health system strengthening regarding NTDs but difficult to put in place (Amazigo, 2008, Brown, 2007).

. One aspect in particular favour for NTD programmes at global, regional and country level is the donated medicines which for LF is able to cover the entire targeted population at risk whilst for SCH currently has strictures, with a known

bottleneck in supply for treatment of adults, the yet to be introduced paediatric formulation and the packaging of the medicines of 1000 tablets per bottle which makes it difficult during the distribution. Expanding the recipients of the medicines for SCH and STH by the NTD programme will interrupt transmission quicker and increase the progress to elimination.

Looking to the future, integrating NTDs should also consider a OneHealth approach, especially when there are growing suspicions of underlying zoonotic potential (Stothard et al., 2020, Webster et al., 2019). This calls for immediate expansion for integration and making surveillance a core intervention in the NTD programme which embraces more research-led activities to go beyond the immediate remit of the ministry programme. Intersectoral collaboration to bring together human health, environmental health and veterinary health on control and elimination of zoonoses to be established.

Introduction, expansion and strengthening of integrated vector control in the elimination programme for LF and for SCH, and the provision of safe water, sanitation and hygiene for STH and SCH which are key. The Zambia Health in All Policies is a platform on which these interventions requiring multi-sectoral and multi-stakeholder involvement should be covered (GRZ, 2018). Multisectoral approach to NTD prevention and control using high office the Vice President to take the lead as the agenda for Health in All Policies is being strengthened.

Integrating NTD interventions with other community-based health interventions such as childhood immunisation and the social cash transfer scheme that target those communities that live in hard to reach areas will facilitate the expansion of the programme. Increase awareness through social media which is a modern way of sharing information especially on climate change and possible impact on change of transmission. There is also a need to decentralise the development of joint action plans to improve ownership, collaboration, and sustainability. Integration and customisation of reporting tools into the MoH health information systems. To make up on lost time, Zambia should increase the number of treatment rounds and the integrate all the 3 NTDs.

6.3 Future aspects to consider from a 2030 perspective

The focus for Zambia for 2030 is to eliminate the three PC NTDs. However, this will not be possible for the three diseases if current interventions remain the same. Several gaps have been identified and our 2030 targets should address them. There are deficits in epidemiological data collection as follows:

6.3.1 Disease tracking through time

Cross-sectional disease surveys whilst informative need to be augmented with appraisal of the temporal dynamics of disease. It is therefore necessary to conduct additional epidemiological surveys in selected sites (e.g. sentinels) for monitoring both the prevalence and intensity of infections, as well as associated morbidities. Currently this is lacking in Zambia but should be an essential future component of the control programme to keep a 'finger-on-the-pulse' of the impact of current and future interventions. Within this expanded programme of surveillance inclusion of currently poorly served at-risk groups should be considered.

6.3.2 At-risk groups currently underserved

To collect data on PreSAC infection (STH & SCH), burden and distribution which is currently not a part of the mapping guideline by 2021. MDAs for SCH and STH to include secondary schools to reach the SAC that have already crossed over from primary schools. The approach should be both school and community based. About SCH, estimation of numbers of adolescent and adult women with female genital schistosomiasis and better distribution of praziquantel in sexual and reproductive health clinics is recommended. This will need some geographical targeting which should make use of current and future disease control/infection prevalence maps.

6.3.3 Geographical tailoring between district level

Unlike LF and STH, SCH is focal disease such that the local disease landscape is uneven. Therefore, the at-risk target should not be at district level but rather at subdistrict level. In so doing, the wastage of already limited supplies of praziquantel would be reduced which means it is possible to expand broader community access (i.e. all demographic groups in need) at local levels. The high geographical clustering of *Ascaris* only on the Copperbelt Province should be investigated perhaps alongside genotyping of worms to assess if there is zoonotic potential with surveillance of infection for example in pigs. By contrast, my study did not find any of the predictors

tested to be associated with hookworm even though hookworm is highly endemic in Zambia. Examination for confounding factors would help for the elimination programme. Furthermore, we should note that NTD medicines do not always reduce overt morbidity already present in individuals with advanced disease, nonetheless the NTD programme should take a more holistic approach to reduce suffering.

6.3.4 Attention on individual morbidity management plans

The central theme of this thesis has been on preventive chemotherapy in the first instance, however, individual morbidity management of LF is needed and this is very poorly served in Zambia. In line with recent impetus on female genital schistosomiasis, Zambia does not have a tailored strategy not only to recognise this need but also put in place an effective strategy to assist those women with the condition who may or may not have HIV. To do so as a first step the Zambia health system must recognise and address the lack of access of NTD medicines for routine treatment within health centres. Seminal clinical case studies on schistosomiasis are needed and have been neglected for a very long time. It is disappointing that Zambia has never had a sustained clinical intervention against this disease which has beset by sporadic interventions. The morbidity associated with gynaecological disease should be quantified, especially in already identified hotspot clusters and we should not overlook aspects of male genital schistosomiasis considering HIV transmission too.

6.4 Future Research

My study has generated research questions that requiring further investigations. Considering the activities that should be better addressed for 2030, there is a need within the Zambian health system to restructure, to assess the mechanism of joint planning and requirements with other disease programmes for sustainability and acceptability preventive chemotherapy. Note that Zambia is moving towards the elimination of malaria which is also introducing MDAs, so many other community and school interventions are taking place. Keeping a high-level insight across disease programmes, and avoid silos, is needed and a KAP across intervention stakeholders on this would be very informative to better plan and co-ordinate intervention, especially as the transmission environments will change with expected climate change.

The other research questions generated from Chapter three include the assessment of causal relationship between ITN and LF prevalence and the direction of the relationship. More studies to be embarked on to come up with newer products or insecticides for vector control as mosquitoes were resistant to most of the chemicals and why there is still high prevalence in LF prevalence in the border with DRC.

In chapter four, there were grey areas requiring more research which include the need to assess why there is high prevalence of SCH in the western part of the country and the peri-urban area infection in the capital city (Lusaka). No morbidity studies including the extent and distribution have been conducted for SCH. Further, malacological, ethnicity and immunological influencers in infectivity rates by gender to ascertain why the gender difference for the different species. With climate change, research to mitigate the adaptive changes in parasites and vector survival and also to investigate the unusual finding of low correlation between SCH and STH prevalence in Zambia.

From Chapter five, additional studies to assess potential costs of coordination (multisectoral and multistakeholder) and the various roles of partners in integration and the opportunity costs should be documented.

Appendices

Appendix 1. Publications and conference presentations related to the thesis and general NTDs work

Thesis related publications and conference poster (see over next 3 pages)

1. Mapping the geographical distribution of lymphatic filariasis in Zambia. Mwase ET, Stensgaard AS, **Nsakashalo-Senkwe** M, Mubila L, Mwansa J, Songolo P, Shawa ST, Simonsen PE. PLoS Neglected Tropical Diseases. 2014 Feb 20;8(UHC 2030):e2714. doi: 10.1371/journal.pntd.0002714. eCollection 2014 Feb.

2. Significant decline in lymphatic filariasis associated with nationwide scale-up of insecticide-treated nets in Zambia**. Nsakashalo-Senkwe M**, Mwase E, Chizema-Kawesha E, Mukonka V, Songolo P, Masanhinga F, Rebollo MP, Thomas B, Bockarie M, Betts H, Stothard JR, Kelly-Hope LA. 2017. Parasite Control and Epidemiology 2: 7-14

3. Programmatic implications of extensive vector control on elimination of lymphatic filariasis in Zambia**. Nsakashalo-Senkwe M**, Stanton M, Mwase E, Chizema-Kawesha E, Mukonka V, Songolo P, Masanhinga F, Rebollo MP, Thomas B, Bockarie M, Betts H, Stothard JR, Kelly-Hope LA. International Conference presentation poster – American Society of Tropical Medicine – October 2015, New Orlean, USA

NTD related publication

1. The use of Loop-mediated Isothermal Amplification (LAMP) to detect the re-emerging Human African Trypanosomiasis (HAT) in the Luangwa and Zambezi valleys.Namangala B, Hachaambwa L, Kajino K, Mweene AS, Hayashida K, Simuunza M, Simukoko H, Choongo K, Chansa P, Lakhi S, Moonga L, Chota A, Ndebe J, **Nsakashalo-Senkwe** M, Chizema E, Kasonka L, Sugimoto C. Parasites and Vectors. 2012 Dec 4;5:282. doi: 10.1186/1756-3305-5-282.

Other publication

1. Combined prevalence of impaired glucose level or diabetes and its correlates in Lusaka urban district, Zambia: a population based survey. **Nsakashalo-Senkwe** M, Siziya S, Goma FM, Songolo P, Mukonka V, Babaniyi O. International Archives of Medeicine. 2011 Jan 12;4(1):2. doi: 10.1186/1755-7682-4-2.

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PLOS | NEGLECTED TROPICAL DISEASES

Mapping the Geographical Distribution of Lymphatic Filariasis in Zambia

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Abstract

Background: Past case reports have indicated that lymphatic filariasis (LF) occurs in Zambia, but knowledge about its geographical distribution and prevalence pattern, and the underlying potential environmental drivers, has been limited. As a background for planning and implementation of control, a country-wide mapping survey was undertaken between 2003 and 2011. Here the mapping activities are outlined, the findings across the numerous survey sites are presented, and the ecological requirements of the LF distribution are explored.

Methodology/Principal findings: Approximately 10,000 adult volunteers from 108 geo-referenced survey sites across Zambia were examined for circulating filarial antigens (CFA) with rapid format ICT cards, and a map indicating the distribution of CFA prevalences in Zambia was prepared. 78% of survey sites had CFA positive cases, with prevalences ranging between 1% and 54%. Most positive survey sites had low prevalence, but six foci with more than 15% prevalence were identified. The observed geographical variation in prevalence pattern was examined in more detail using a species distribution modeling approach to explore environmental requirements for parasite presence, and to predict potential suitable habitats over unsurveyed areas. Of note, areas associated with human modification of the landscape appeared to play an important role for the general presence of LF, whereas temperature (measured as averaged seasonal land surface temperature) seemed to be an important determinant of medium-high prevalence levels.

Conclusions/significance: LF was found to be surprisingly widespread in Zambia, although in most places with low prevalence. The produced maps and the identified environmental correlates of LF infection will provide useful guidance for planning and start-up of geographically targeted and cost-effective LF control in Zambia.

Citation: Mwase ET, Stensgaard A-S, Nsakashalo-Senkwe M, Mubila L, Mwansa J, et al. (2014) Mapping the Geographical Distribution of Lymphatic Filariasis in Zambia. PLoS Negl Trop Dis 8(2): e2714. doi:10.1371/journal.pntd.0002714

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Introduction

Little has been reported about lymphatic filariasis (LF) in Zambia in the past. According to Buckley [1], local medical reports from the 1930's and 1940's mentioned the recovery of microfilariae (mf) of *Wuchereria bancrofti* from patients in Zambia, but the history and movements of the infected individuals did not rule out the possibility that infections had been acquired elsewhere. These reports also mentioned that the condition of elephantiasis was seen in Zambia and was commonly referred to as "Serenje leg" or "Feira leg" after its frequent occurrence in the districts of Serenje and Feira (now Luangwa). In 1946, Buckley identified a few cases of *W. bancrofti* microfilaraemia in hospital patients in Lusaka, Ndola and Kasama, but none of the infected individuals had been permanent residents in the country [1]. During a small night blood survey carried out in Luangwa valley, Barclay [2] failed to identify *W. bancrofti* mf. In contrast, both Buckley and Barclay reported high prevalences of infection with another human filaria, *Mansonella perstans*, from their surveys.

The first definite autochthonous case of LF due to *W. bancrofti* in Zambia was reported in 1975 by Hira [3,4] from a 25-year old fisherman from Luangwa who presented with a tender swelling in the right inguinal fossa and swollen ankles. Hira [4,5] afterwards observed more patients with *W. bancrofti* mf in Zambia, including cases acquired locally as well as cases that could have been acquired in neighboring countries. More recently, *W. bancrofti* mf were also reported from a 22-year old male from Southern Province [6] and from a 49-year old female from Northern Province who suffered from lower limb and vulval elephantiasis [7].

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Significant decline in lymphatic filariasis associated with nationwide scale-up of insecticide-treated nets in Zambia

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ABSTRACT

Lymphatic filariasis (LF) is a mosquito-borne disease, broadly endemic in Zambia, and is targeted for elimination by mass drug administration (MDA) of albendazole and diethylcarbamazine citrate (DEC) to at-risk populations. Anopheline mosquitoes are primary vectors of LF in Africa, and it is possible that the significant scale-up of malaria vector control over the past decade may have also impacted LF transmission, and contributed to a decrease in prevalence in Zambia. We therefore aimed to examine the putative association between decreasing LF prevalence and increasing coverage of insecticide-treated mosquito nets (ITNs) for malaria vector control, by comparing LF mapping data collected between 2003–2005 and 2009–2011 to LF sentinel site prevalence data collected between 2012 and 2014, before any anti-LF MDA was started. The coverage of ITNs for malaria was quantified and compared for each site in relation to the dynamics of LF. We found a significant decrease in LF prevalence from the years 2003–2005 (11.5% Cl_{95} 6.6; 16.4) to 2012–2014 (0.6% Cl_{95} 0.03; 1.1); at the same time, there was a significant scale-up of ITNs across the country from 0.2% (Cl_{95} 0.0; 0.3) to 76.1% (Cl_{95} 71.4; 80.7) respectively. The creation and comparison of two linear models demonstrated that the geographical and temporal variation in ITN coverage was a better predictor of LF prevalence than year alone. Whilst a causal relationship between LF prevalence and ITN coverage cannot be proved, we propose that the scale-up of ITNs has helped to control *Anopheles* mosquito populations, which have in turn impacted on LF transmission significantly before the scale-up of MDA. This putative synergy with vector control has helped to put Zambia on track to meet national and global goals of LF elimination by 2020.

1. Introduction

Lymphatic filariasis (LF) is a mosquito-borne disease, which is widely endemic in Zambia. Overall prevalence rates were estimated at 7.4% in 2011 from > 10,000 sampled individuals across 108 sites in all regions of the country by rapid circulating filarial antigen (CFA; a marker of the *Wuchereria bancrofti* adult worm infection) BinaxNOW Filariasis immunochromatographic test (ICT) card (Mwase et al., 2014). The initial mapping started in 2003 and 2005 at 42 sites across 14 districts thought to be endemic for LF.

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Programmatic implications of extensive vector control on elimination of Lymphatic Filariasis in Zambia

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Introduction

Lymphatic filariasis (LF) is considered to be widely endemic in Zambia, and the National LF Programme is planning the first nationwide mass drug administration (MDA) to interrupt transmission. During surveys conducted in the 2000s, overall prevalence was found to be relatively low with most locations <10%, and only some areas reporting rates >50%.

Zambia is a unique country in that it has very high coverage of vector control for malaria, which has scaled up significantly over the past decade. Given that malaria and LF are transmitted by the same Anopheles species, it is therefore possible that the well established vector control programme has already impacted LF transmission.

To better understand the distribution of vector control that has occurred across the country and the potential implications for the LF Programme, this study examined and mapped levels of vector control in relation to the surveys carried across 108 geo-referenced sites between 2003 and 2010 and the compared it to sentinel sites data collected across 41 geo-referenced sites in 2013-2014.

Methods

Prevalence data: Information from the 108 survey sites was obtained from Ministry of Health. Information from the 41 sentinel site data collected in 2013-2014 was based in the rapid ICT diagnostic for LF antigen, and night bloods on ICT positive people to detect microfilaria (MFs) (Figure 1).

Vector control data: Information on bed nets including long lasting/ insecticide treated bed nets (LLIN/ITNs) was obtained from the Ministry of Health. The percentage (%) of bednet coverage for each district was given a score ranging from 1 (0-20%) to 5 (>8%) multiplied by 7 years.

Analysis and mapping: First, the LF prevalence data were compared by the different years. Second, vector control data were collated and combined in a weighted sum to form a bednet score which was then combined with low (<10%) and high (≥10%) LF prevalence rates from 2003-2010.

Each district was then classified according to LF prevalence and the bed net score which included the following combinations

i) Low bednet / high LF
ii) High bednet /high LF
iii) Low bednet / low LF
iv) High bednet / low LF

These were mapped in ArcGIS (ESRI 10.1, Redland, CA) to highlight potential high risk areas – and compare them to the 2013-14 data.

Figure 1a. Positive ICT card

Figure 1b. microfilaria

Results

The average LF prevalence in each survey year decreased over time from 23.7% in 2003 to 0.3% in 2013-14 as shown in Figure2. The most significant decrease in LF prevalence occurred between 2005 and 2009 when bednets scaled up across the country as shown in Figure 3. A number of districts has over 80% report coverage for more than 3 years

Figure 2. Average LF prevalence by year by ICT card

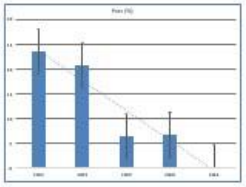
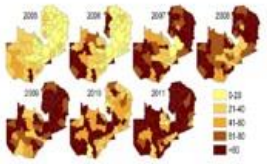
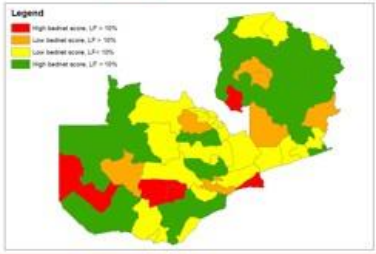


Figure 3. Maps of bednets distribution scale up between 2005-2011



Bednet score / LF prevalence map. Shown in Figure 4 is the bednet score (which is calculated using the reported bednet coverage between 2005-2011) against LF prevalence. There are four categories i.e. high bed net score (score >=24) & high LF prevalence (>10%) (RED), high bed net score and low LF prevalence (GREEN), low bed net score and high LF prevalence (ORANGE), and low bed net score and low prevalence (YELLOW). The RED districts are therefore those that have had high bed net coverage for a number of years, but have high LF prevalence.

Figure 4. A map of bednet / LF prevalence classifications

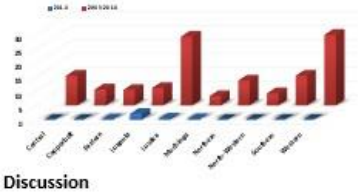


Results

When the overall provincial prevelance in 2003-2010 was compare to 2013-1014 in the 41 selected sites shown in Figure 5, a significant reduction was shown in all areas of the country (Figure 6.

Figure 5. Sentinel sites in 2013-2014

Figure 6. Comparison of provincial level ICT positives rates in 2003-2010 and in 2013-2014



Discussion

The significant reductions in LF prevalence over the last decade before any MDA has started may be attributed to the extensive national scale up of vector control. This study to date has only examined the potential impact of bednets/LLINs and it is likely that the IRS activities also ongoing in Zambia have had a further impact. This is very potentially very good news for the LF programme as it may be able to interrupt transmisssion completely with a reduced number of years of MDA. However, plans to assess this are already in place for 2015 and are expected to yield very promising results.

Acknowledgements

We are grateful to the community members who participated in the recent sentinel site study, and the field assistants who helped collect the data. We also thank the Ministry of Health for the LF prevalence and bed net information, and the Department for International Development (DFID), UK for funding support for this study.

Large-scale distribution of schistosomiasis in Zambia: Mapping by Province District and School to predict projections of treatment needs

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Introduction

Schistosomiasis (SCH) is a waterborne infection caused by trematode worms (blood flukes) of the genus Schistosoma. Two types are endemic in Zambia- *S. heamatobium* and *S. Mansoni* but the distribution of SCH and the contributing factors are not well documented. However, the focality of SCH requires more detailed mapping highlighting the communities and point prevalence.

To better understand the distribution of SCH and the contributing factors there was need to compile comprehensive information on the prevalence of SCH and enhance the knowledge of spatial distribution for planning of control strategies.

Therefore, as part of the national control programme against schistosomiasis in Zambia, the prevalence of egg-patent schistosomiasis was determined in a total of 1,349 primary schools across the country.

Methods

In order to define and map the provincial, district and school level prevalence, between 2011-2012, survey teams visited 1349 schools and 30 children, of balanced gender, were examined using faecal Kato-Katz (41.7mg) and urine filtration (10ml) methods.

Selection of schools was purposeful and from each ecological zone covering the sub-district areas. GPS coordinates were recorded for each school. The indicator for each stool collected, Kato Katz was used to look for *S. mansoni* eggs and urine filtration and microscopy for presence of *S. heamtobium* eggs. PZQ was given to individuals that tested positive. Data were collected using paper forms and stored by supervisors.

Analyses were performed using SPSS version 24 (IBM SPSS statistics 24) and prevalence maps produced using QGIS & ArcGIS. Confidence intervals for prevalence were set at 95%. The prevalence of schistosomiasis was determined for each site. High and low risk clustering was determined using ArGIS staila analysis tool and the Getis Ord statistic (hotspot analysis).
Environmental factors to be considered include elevation, rainfall, temperature and eco-zones from World clim data (http://www.worldclim.org/)

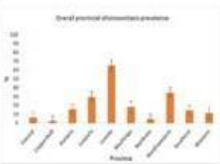
Results

39,904 individuals were tested across Zambia. National prevalence was 17.4% for any SCH while it was 15.2% and 2.8% for urogenital and intestinal disease, respectively. Provincial SCH prevalence ranged from 2.6-65.1; District level SCH prevalence ranged from 0-87.7%; and Site level prevalence ranged from 0-100%

Table1. Summary table of overall SCH prevalence at provincial and national level

Province	Mean	N	Std. Deviation	Std. Error of Mean	95% Confidence Interval Lower	95% Confidence Interval Upper
Central	6.35797	142	[illegible]	[illegible]	4.9071	[illegible]
Copperbelt	2.60686	175	[illegible]	[illegible]	[illegible]	[illegible]
Eastern	15.45874	137	[illegible]	[illegible]	[illegible]	[illegible]
Luapula	29.54168	136	[illegible]	[illegible]	[illegible]	[illegible]
Lusaka	65.14075	88	[illegible]	[illegible]	[illegible]	[illegible]
Muchinga	18.35887	87	[illegible]	[illegible]	[illegible]	[illegible]
Northern	4.36998	147	[illegible]	[illegible]	[illegible]	[illegible]
Northwestern	34.38781	119	[illegible]	[illegible]	[illegible]	[illegible]
Southern	13.98856	180	[illegible]	[illegible]	[illegible]	[illegible]
Western	11.43843	108	[illegible]	[illegible]	[illegible]	[illegible]
Total	17.42164	1339	[illegible]	[illegible]	[illegible]	[illegible]

Figure 2. Overall Provincial prevalence



The patterns of disease differed at province and district-levels, and could also be clustered across nearby schools evidencing the well-known focality of either form of schistosomiasis.

Figure 3. Prevalence of SCH at district level

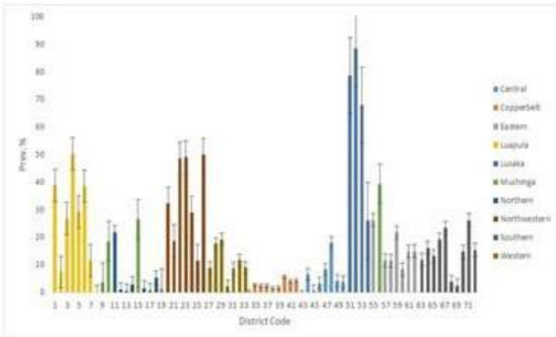


Figure 5. Prevalence of SCH at school level

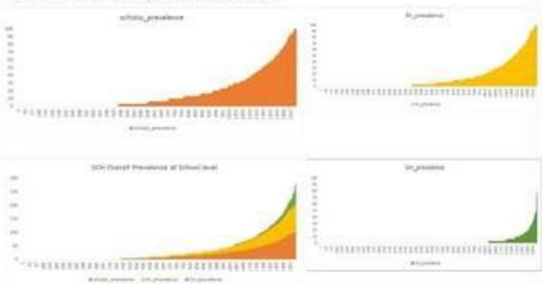
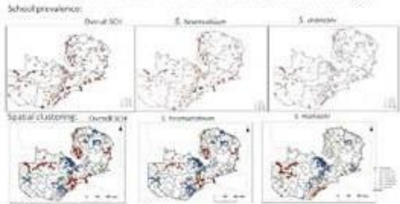


Figure 6. Point Prevalence and Spatial clustering



Discussion

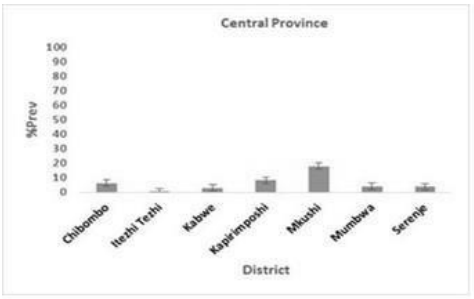
There is clear distinction on the wide geographic distribution of the two schistosomiasis species in Zambia. Where *S. mansoni* is present there are indications that it is intense. A high proportion of these schools have a residual *S. mansoni* on top of the expanding *S. heamatobium*. High risk areas are that will require yearly MDA and moderate risk areas requiring biennial MDA have been identified in 13.3% and 33.3% schools respectively. There was significantly high clusters with >2.58 Std. Dev and significantly low cluster of <-2.58 std. Dev. Further analysis is being performed to identify any association with environmental factors in the hotspots.

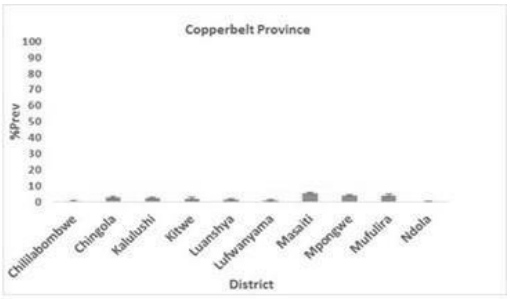
Acknowledgements

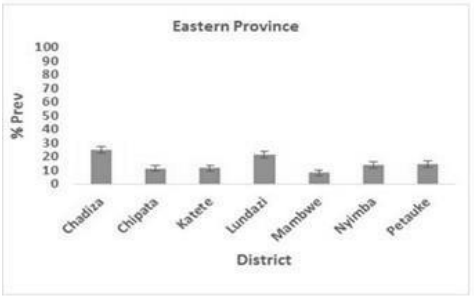
We are grateful to the community members who participated in the mapping survey, surveys team members who helped collect the data. We also thank the Ministry of Health and the ethics committee who permitted the surveys and the Department for International Development (DFID), UK for funding support.

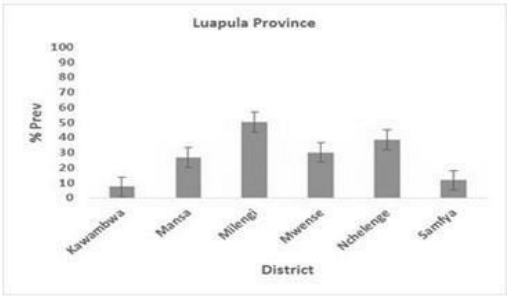
Appendix 2 Graphs

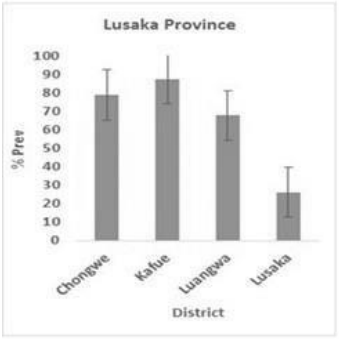
Overall schistosomiasis prevalence by district per province

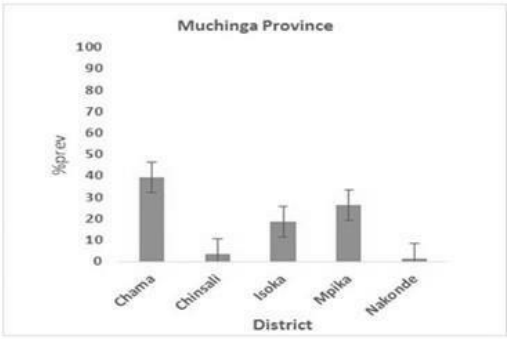


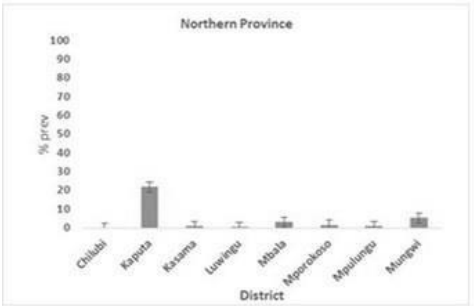


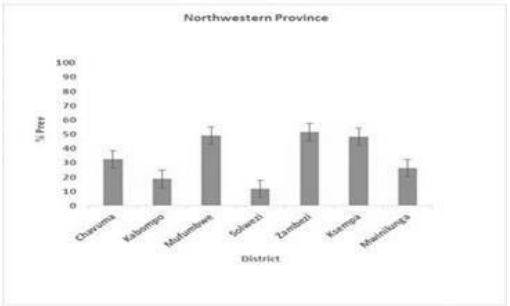


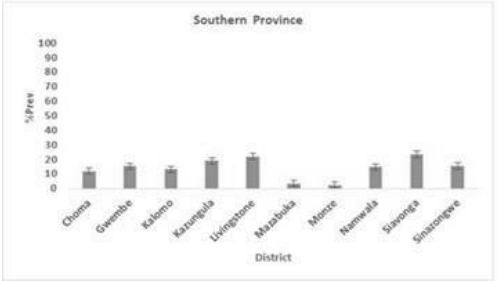


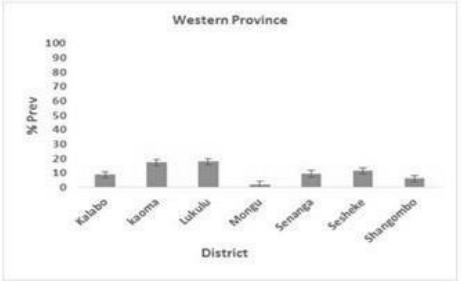




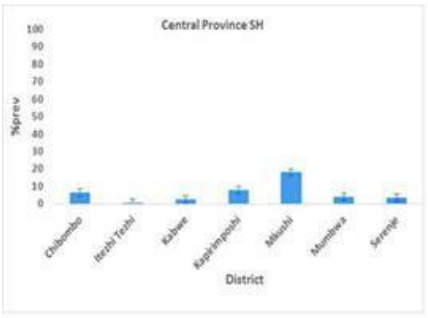


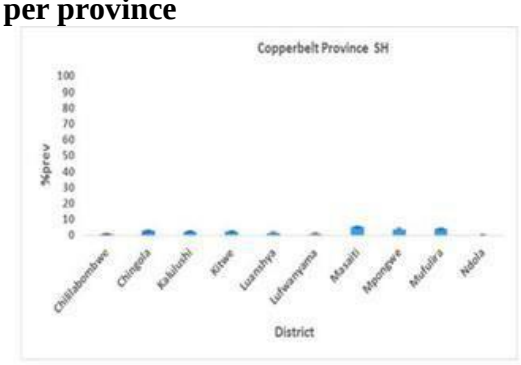


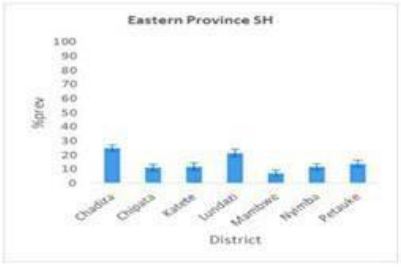


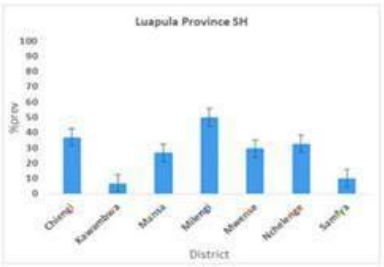


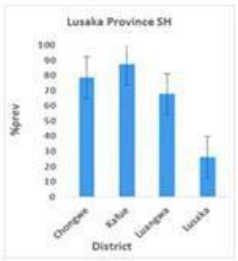
S. haematobium prevalence by district per province

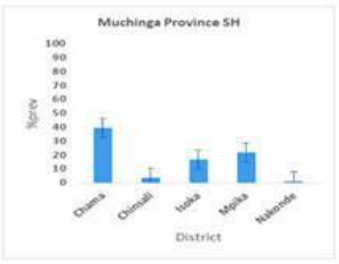


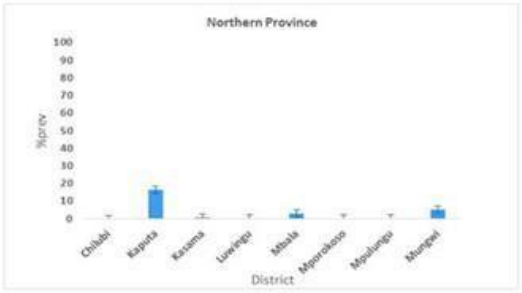


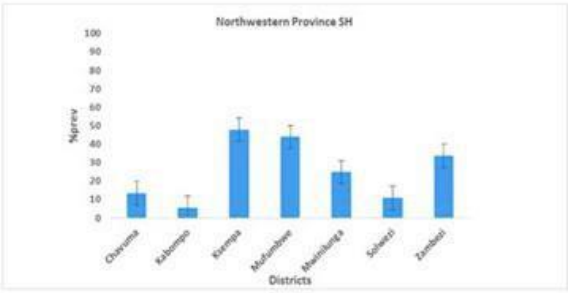


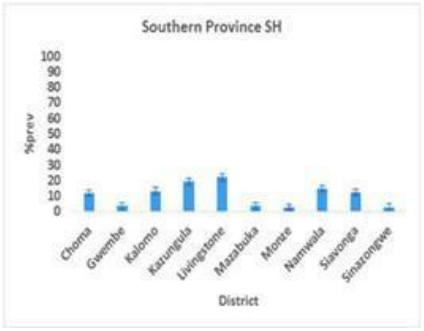


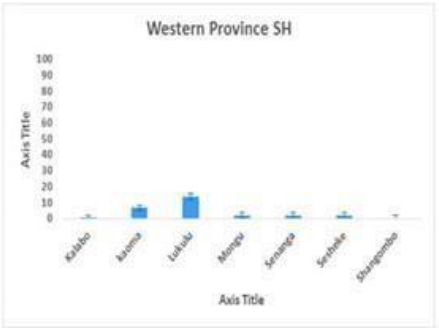




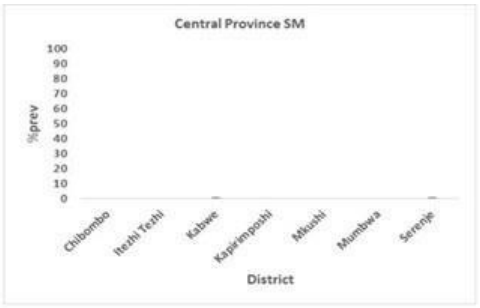


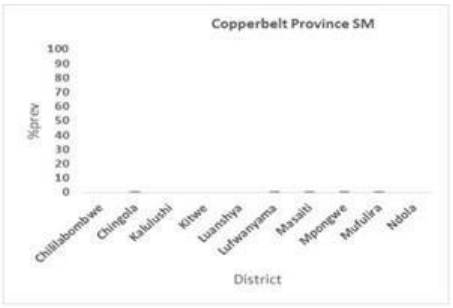


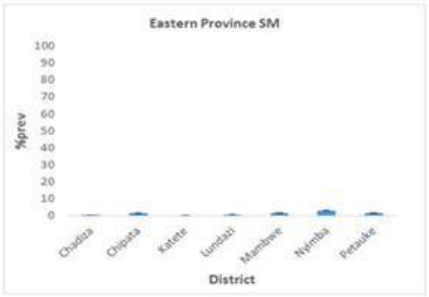


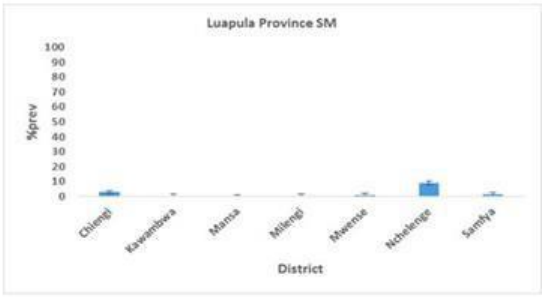


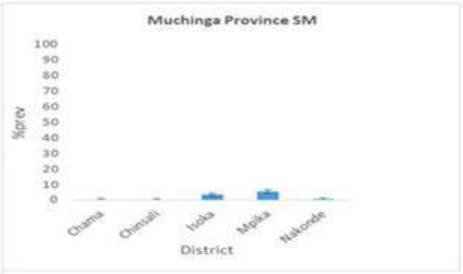
S. mansoni prevalence by district per province

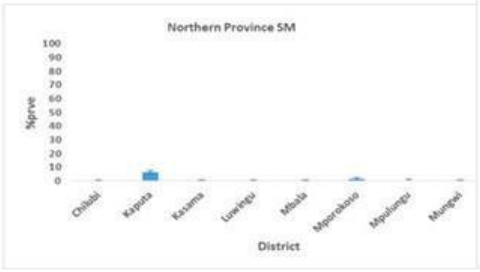


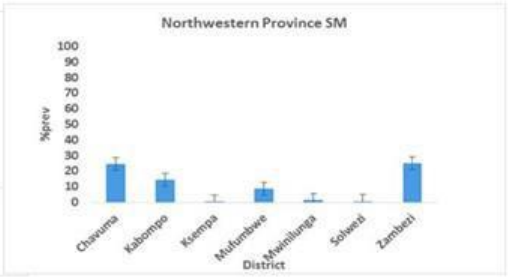


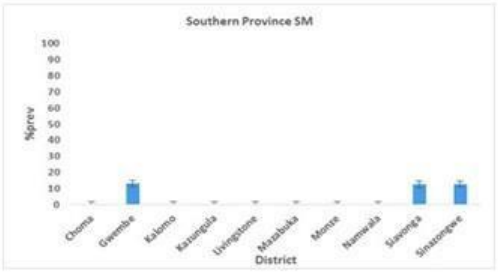


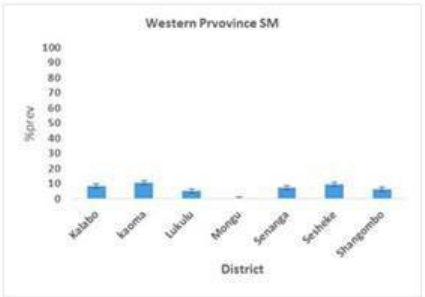












Appendix 2 Tables

Table 1 Population at risk and requiring treatment

Province	District	District Population	Endemicity	Total Pop requiring treatment	Pre-SAC	SAC
Central	Chibombo	446706	Low	62582	10720	51862
Central	Itezhi-tezhi	87176	Low	12213	2092	10121
Central	Kabwe	221007	Low	36264	5304	30960
Central	Kapiri Mposhi	294971	Low	48404	7079	41325
Central	Mkushi	188071	Moderate	79995	7522	43914
Central	Mumbwa	273869	Low	44940	6572	38368
Central	Serenje	190392	Low	31242	4569	26673
TOTAL		**1702192**		**315640**	**43858**	**243223**
Copperbelt	Chililabombwe	114282	Low	18752	2742	16010
Copperbelt	Chingola	259981	Low	42662	6239	36423
Copperbelt	Kalulushi	123359	Low	20242	2960	17282
Copperbelt	Kitwe	646827	Low	106143	15523	90620
Copperbelt	Luanshya	172170	Low	28251	4131	24120
Copperbelt	Lufwanyama	93622	Low	15362	2246	13116
Copperbelt	Masaiti	116244	Low	19074	2789	16285
Copperbelt	Mpongwe	119712	Low	19643	2872	16771
Copperbelt	Ndola	530129	None	0	0	0
Copperbelt	Mufulira	185844	Low	30496	4460	26036
TOTAL		**2362170**		**300625**	**43962**	**256663**
Eastern	Chipata	508361	Moderate	208122	20334	118702
Eastern	Lundazi	378225	Moderate	151962	14075	82163
Eastern	Petauke	351876	Moderate	135864	11079	64677
Eastern	Katete	276991	Moderate	93343	3746	21869
Eastern	Nyimba	93659	Moderate	41384	4858	28359
Eastern	Chadiza	121456	Moderate	45502	3315	19351
Eastern	Mambwe	82877	Low	13599	1989	11610
TOTAL		**1813445**		**689776**	**59396**	**346731**
Luapula	Chienge	133501	Moderate	54655	5340	31172
Luapula	Nchelenge	179352	Moderate	73426	7174	41878
Luapula	Milenge	54127	High	54127	4330	25277
Luapula	Mansa	257517	Moderate	105426	10300	60130
Luapula	Kawambwa	154294	Low	25336	3720	21616
Luapula	Samfya	170327	Moderate	69731	6813	39771
Luapula	Mwense	220327	Moderate	90201	8813	51446
TOTAL		**1169445**		**472902**	**46490**	**271290**
Lusaka	Chongwe	230400	High	230400	18432	107596
Lusaka	Kafue	282998	High	282998	22639	132160
Lusaka	Luangwa	27954	High	27954	2236	13054
Lusaka	Lusaka	2236090	Moderate	915454	89443	522127
TOTAL		**2777442**		**1456806**	**132750**	**774937**
Muchinga	Nakonde	161472	Low	26497	3875	22622

Province	District	District Population	Endemicity	Total Pop requiring treatment	Pre-SAC	SAC
Muchinga	Chama	131514	Moderate	53840	5260	30708
Muchinga	Isoka	175759	Moderate	71955	7030	41039
Muchinga	Mpika	257786	Moderate	105537	10311	60193
Muchinga	Chinsali	168527	Low	27654	4044	26610
TOTAL		**895058**		**285483**	**30520**	**181172**
Northern	Chilubi	90158	None	0	0	0
Northern	Kaputa	141053	Moderate	57746	5642	32935
Northern	Kasama	272238	Low	44674	6533	38140
Northern	Luwingu	151932	Low	24932	3646	21285
Northern	Mbala	238660	Low	39164	5727	33436
Northern	Mporokoso	115301	Low	18920	2767	16153
Northern	Mpulungu	118886	Low	19509	2853	16655
Northern	Mungwi	176207	Low	28915	4228	24686
TOTAL		**1304435**		**233860**	**31396**	**183290**
North Western	Chavuma	38969	Moderate	15953	1558	9099
North Western	Kabompo	107732	Moderate	45605	4309	25155
North Western	Kasempa	82549	Moderate	33794	3301	19275
North Western	Mufumbwe	68337	Moderate	27976	2733	15956
North Western	Mwinilunga	117995	Moderate	48305	4719	27551
North Western	Solwezi	291876	Moderate	68153	11675	68153
North Western	Zambezi	126360	High	126360	10108	59010
TOTAL		**833818**		**366146**	**38403**	**224199**
Southern	Choma	276733	Moderate	113294	11069	64617
Southern	Gwembe	66781	Moderate	27339	2671	15593
Southern	Mazabuka	250275	Low	41070	6006	35063
Southern	Kalomo	321627	Moderate	131673	12865	75099
Southern	Kazungula	130790	Moderate	53544	5231	30539
Southern	Namwala	116337	Moderate	47627	4653	27164
Southern	Monze	211112	Low	34643	5066	29576
Southern	Siavonga	112606	Moderate	46100	4504	26293
Southern	Sinazongwe	115823	Moderate	47416	4632	27044
Southern	Livingstone	164157	Moderate	57205	6566	28330
TOTAL		**1766241**		**599911**	**63263**	**359318**
Western	Kalabo	113043	Low	18550	2713	15837
Western	Kaoma	173316	Moderate	70054	6032	40469
Western	Lukulu	67192	Moderate	27507	2687	15689
Western	Mongu	191186	Low	31373	4588	26785
Western	Senanga	109582	Low	17982	2629	15352
Western	Sesheke	140903	Moderate	57685	5636	32900

Province	District	District Population	Endemicity	Total Pop requiring treatment	Pre-SAC	SAC
Western	Shang'ombo	166278	Low	27286	3990	23295
TOTAL		**961500**		**250437**	**28275**	**170327**
NATIONAL	**72**	**15585746**		**4971586**	**518313**	**3011150**

Table 2 District prevalence of STH (all), *A. lumbricoides*, hookworm and *T. trichiura*

Province	District	STH		*A. lumbricoides*		hookworm		*T. trichiura*	
		%	CI_{95}	%	CI_{95}	%	CI_{95}	%	CI_{95}
Central	Chibombo	4.2	2.9-5.9	1.2	0.5-2.9	2.8	1.7-4.8	0.3	0.0-2.3
Central	Itezhi Tezi	0.8	0.3-2.2	0.8	0.3-2.2	0.0	0.0-0.0	0.0	0.0-0.0
Central	Kabwe	1.8	0.9-3.7	1.3	0.6-3.0	0.5	0.1-2.1	0.0	0.0-0.0
Central	Kapirimposhi	30.7	24.8-37.3	1.7	0.7-4.0	29.7	23.7-36.4	0.0	0.0-0.0
Central	Mkushi	18.3	13.6-24.2	0.2	0.0-1.2	18.3	13.6-24.2	0.0	0.0-0.0
Central	Mumbwa	2.3	1.1-4.9	2.2	0.9-4.9	0.2	0.0-1.2	0.0	0.0-0.0
Central	Serenje	16.0	12.6-20.1	0.8	0.3-2.5	15.2	11.8-19.3	0.2	0.0-1.2
Copperbelt	Chililabombwe	33.4	24.8-43.3	10.5	5.3-19.8	21.0	13.4-31.4	2.4	0.8-6.9
Copperbelt	Chingola	11.8	7.8-17.4	7.9	4.4-13.8	3.9	1.8-8.0	0.2	0.0-1.5
Copperbelt	Kalulushi	20.9	10.7-36.8	14.5	6.3-30.0	6.4	2.8-14.1	0.3	0.0-2.4
Copperbelt	Kitwe	35.2	26.9-44.4	34.8	26.5-44.2	0.2	0.0-1.2	0.2	0.0-1.2
Copperbelt	Luanshya	19.7	12.0-30.6	18.3	10.6-29.9	1.3	0.5-3.2	0.0	0.0-0.0
Copperbelt	Lufwanyama	33.7	27.8-40.2	3.9	2.4-6.0	28.2	22.5-34.8	3.2	1.8-5.5
Copperbelt	Masaiti	16.2	10.6-23.9	0.5	0.2-1.5	15.0	9.3-23.3	0.7	0.2-2.1
Copperbelt	Mpongwe	26.8	19.0-36.4	1.8	0.9-3.4	24.4	16.8-34.0	1.1	0.4-2.7
Copperbelt	Mufulira	50.7	41.5-59.9	40.2	29.0-52.6	10.8	5.5-20.1	1.0	0.4-3.0
Copperbelt	Ndola	9.5	4.3-19.8	9.2	4.0-19.8	0.2	0.0-1.2	0.2	0.0-1.2
Eastern	Chadiza	16.5	11.9-22.5	0.3	0.1-1.3	16.2	11.4-22.4	0.0	0.0-0.0
Eastern	Chipata	3.3	2.1-5.2	0.2	0.0-1.2	3.2	2.0-5.0	0.0	0.0-0.0
Eastern	Katete	12.8	9.1-17.7	1.4	0.6-3.2	11.9	8.2-17.1	0.0	0.0-0.0
Eastern	Lundazi	12.5	6.8-21.9	1.0	0.4-2.6	11.5	6.1-20.7	0.0	0.0-0.0
Eastern	Mambwe	7.8	4.7-12.7	1.5	0.6-3.9	6.2	3.6-10.4	0.2	0.0-1.2
Eastern	Nyimba	15.7	12.0-20.2	7.3	5.1-10.5	9.0	5.7-13.9	0.0	0.0-0.0
Eastern	Petauke	20.7	15.0-27.8	13.3	9.8-17.9	8.2	5.2-12.8	0.0	0.0-0.0
Luapula	Chiengi	18.1	13.7-23.6	0.5	0.2-1.5	17.4	13.0-23.0	0.3	0.0-2.4
Luapula	Kawambwa	10.3	7.5-14.1	0.3	0.1-1.3	9.7	6.8-13.6	0.3	0.1-1.3
Luapula	Mansa	9.0	4.7-16.3	4.3	2.1-8.5	4.0	2.0-7.8	0.7	0.2-2.1
Luapula	Milengi	48.8	41.8-55.9	27.5	22.7-32.9	24.2	20.1-28.8	0.0	0.0-0.0
Luapula	Mwense	10.5	7.6-14.3	2.3	1.4-3.8	7.8	5.3-11.5	0.5	0.2-1.5
Luapula	Nchelenge	14.0	9.6-19.9	0.0	0.0-0.0	14.0	9.6-19.9	0.0	0.0-0.0
Luapula	Samfya	11.8	8.2-16.8	4.0	2.5-6.4	5.7	3.8-8.3	2.2	1.2-3.7
Lusaka	Chongwe	13.5	9.7-18.4	4.6	2.8-7.4	9.3	6.9-12.3	0.0	0.0-0.0
Lusaka	Kafue	18.5	12.7-26.2	7.0	3.9-12.4	12.0	8.9-15.9	0.0	0.0-0.0
Lusaka	Luangwa	21.2	15.8-27.7	10.3	7.6-13.9	12.2	8.8-16.6	0.0	0.0-0.0

Lusaka	Lusaka	19.5	14.3-26.0	9.0	5.7-14.0	10.8	7.5-15.4	0.0	0.0-0.0
Northern	Chama	14.3	9.6-20.8	0.3	0.0-2.3	14.0	9.2-20.7	0.0	0.0-0.0
Northern	Chilubi	50.3	43.0-57.7	1.7	0.9-3.2	49.3	42.0-56.7	0.2	0.0-1.2
Northern	Chinsali	42.7	35.0-50.8	1.1	0.5-2.4	40.6	32.7-49.0	1.1	0.5-2.4
Northern	Isoka	11.7	7.4-17.9	3.3	2.0-5.6	8.3	4.8-14.1	0.0	0.0-0.0
Northern	Kaputa	24.7	19.4-30.8	0.0	0.0-0.0	24.5	19.2-30.7	0.2	0.0-1.3
Northern	Kasama	35.0	27.8-42.9	15.3	11.9-19.4	23.7	16.7-32.5	0.0	0.0-0.0
Northern	Luwingu	23.4	17.0-31.4	1.8	0.8-4.3	20.2	14.3-27.8	1.4	0.6-3.0
Northern	Mbala	13.0	9.7-17.2	4.3	2.4-7.6	8.8	5.9-12.9	0.0	0.0-0.0
Northern	Mpika	23.7	14.7-35.8	2.2	0.6-7.4	22.7	13.9-34.7	0.0	0.0-0.0
Northern	Mporokoso	9.0	5.1-15.3	0.0	0.0-0.0	8.8	5.0-15.0	0.2	0.0-1.2
Northern	Mpulungu	19.8	15.8-24.6	5.7	3.7-8.7	14.2	11.0-18.0	0.5	0.1-2.1
Northern	Mungwi	38.2	32.1-44.6	0.7	0.2-2.1	37.7	31.6-44.1	0.0	0.0-0.0
Northern	Nakonde	21.8	17.3-27.2	0.9	0.4-2.4	20.3	15.7-26.0	0.7	0.2-2.3
Northwestern	Chavuma	39.2	31.6-47.4	0.3	0.0-2.3	39.2	31.6-47.4	0.0	0.0-0.0
Northwestern	Kabompo	38.5	30.9-46.8	0.4	0.1-1.4	38.1	30.4-46.6	0.0	0.0-0.0
Northwestern	Kasempa	49.8	42.3-57.3	1.2	0.5-2.8	47.7	39.6-55.9	0.8	0.2-3.2
Northwestern	Mufumbwe	37.2	31.3-43.5	0.7	0.2-2.1	36.9	30.9-43.2	0.0	0.0-0.0
Northwestern	Mwinilunga	54.6	47.4-61.7	2.6	1.4-4.7	52.6	45.1-60.0	0.2	0.0-1.3
Northwestern	Solwezi	39.4	33.1-46.2	2.3	0.9-5.7	36.8	30.4-43.6	1.5	0.8-2.9
Northwestern	Zambezi	36.9	29.0-45.5	0.4	0.1-1.4	36.7	28.8-45.4	0.0	0.0-0.0
Southern	Choma	8.9	5.8-13.4	4.6	2.6-8.2	4.3	2.0-8.8	0.0	0.0-0.0
Southern	Gwembe	1.4	0.5-3.9	0.0	0.0-0.0	1.4	0.5-3.9	0.0	0.0-0.0
Southern	Kalomo	4.4	2.3-8.5	1.9	0.9-4.0	2.6	0.9-7.5	0.0	0.0-0.0
Southern	Kazungula	2.6	0.7-9.9	0.9	0.2-4.2	1.8	0.2-11.5	0.0	0.0-0.0
Southern	Livingstone	1.2	0.4-3.2	0.8	0.2-2.9	0.2	0.0-1.2	0.2	0.0-1.2
Southern	Mazabuka	3.2	1.2-8.0	0.3	0.0-2.3	2.8	1.0-8.0	0.0	0.0-0.0
Southern	Monze	11.7	8.6-15.6	0.0	0.0-0.0	11.7	8.6-15.6	0.0	0.0-0.0
Southern	Namwala	2.5	0.9-6.8	0.8	0.1-5.7	1.7	0.4-6.1	0.0	0.0-0.0
Southern	Siavonga	2.3	1.4-4.0	0.3	0.1-1.3	2.0	1.0-3.8	0.0	0.0-0.0
Southern	Sinazongwe	3.1	1.9-4.8	0.2	0.0-1.2	2.9	1.7-4.8	0.0	0.0-0.0
Western	Kalabo	34.0	27.5-41.2	0.8	0.3-2.2	33.5	27.0-40.6	0.0	0.0-0.0
Western	Kaoma	37.9	30.9-45.5	0.0	0.0-0.0	37.9	30.9-45.5	0.0	0.0-0.0
Western	Lukulu	49.8	44.2-55.4	0.3	0.1-1.3	49.5	44.0-55.0	0.0	0.0-0.0
Western	Mongu	25.9	18.7-34.7	0.5	0.1-1.7	25.5	18.4-34.1	0.0	0.0-0.0
Western	Senanga	32.0	21.4-44.9	0.3	0.0-2.3	32.0	21.4-44.9	0.0	0.0-0.0
Western	Sesheke	48.5	38.5-58.7	0.0	0.0-0.0	48.3	38.3-58.5	0.2	0.0-0.0
Western	Shangombo	38.7	29.4-48.8	0.0	0.0-0.0	38.3	29.5-48.0	0.3	0.0-2.3
National		21.5		4.2		17.3		0.6	

Table 3 Schistosomiasis prevalence by district

Province	District	SCH		*S. haematobium*		*S. mansoni*	
		%	CI_{95}	%	CI_{95}	%	CI_{95}
Central	Chibombo	6.5	4.1-10.2	6.5	4.1-10.2	0	0-0
Central	Itezhi Tezi	0.5	0.2-1.5	0.5	0.2-1.5	0	0-0
Central	Kabwe	3.2	0.9-10.3	2.7	0.7-9.7	0.7	0.2-2.5
Central	Kapiri Mposhi	8.3	5.3-12.9	8.2	5.1-12.8	0.2	0-1.2
Central	Mkushi	18.0	13.8-23.1	18.0	13.8-23.1	0.0	0.0-0.0
Central	Mumbwa	4.2	1.8-9.2	4.2	1.8-9.2	0.0	0.0-0.0
Central	Serenje	3.8	2.3-6.5	3.5	2.0-6.0	0.7	0.1-3.0
Copperbelt	Chililabombwe	0.2	0.0-1.7	0.2	0.0-1.7	0.0	0.0-0.0
Copperbelt	Chingola	2.8	1.4-5.5	2.6	1.3-5.1	0.2	0.0-1.5
Copperbelt	Kalulushi	2.4	0.8-7.1	2.4	0.8-7.1	0.0	0.0-0.0
Copperbelt	Kitwe	2.3	1.1-4.8	2.3	1.1-4.8	0.0	0.0-0.0
Copperbelt	Luanshya	1.5	0.7-3.3	1.5	0.7-3.3	0.0	0.0-0.0
Copperbelt	Lufwanyama	1.8	0.7-4.1	1.6	0.6-4.1	0.2	0.0-1.2
Copperbelt	Masaiti	5.7	3.6-8.9	5.2	3.0-8.6	0.5	0.2-1.5
Copperbelt	Mpongwe	4.0	1.2-12.6	3.7	1.0-12.8	0.4	0.0-2.4
Copperbelt	Mufulira	4.4	2.1-8.8	4.0	2.0-7.9	0.5	0.1-3.6
Copperbelt	Ndola	0.0	0.0-0.0	0.0	0.0-0.0	0.0	0.0-0.0
Eastern	Chadiza	26.2	18.7-35.3	26.0	18.5-35.3	0.2	0.0-1.2
Eastern	Chipata	11.6	6.1-21.0	11.2	5.8-20.6	1.4	0.4-4.8
Eastern	Katete	11.4	7.6--6.8	11.4	7.6-16.8	0.0	0.0-0.0
Eastern	Lundazi	21.7	13.1-33.6	21.5	13.1-33.3	0.5	0.1-2.1
Eastern	Mambwe	8.3	4.7-14.4	7.0	3.7-12.8	1.5	0.3-8.2
Eastern	Nyimba	14.8	9.6-22.2	12.5	7.4-20.4	2.8	1.4-5.7
Eastern	Petauke	14.9	10.2-21.3	13.8	9.4-19.7	1.6	0.7-3.5
Luapula	Chiengi	38.7	31.9-46.0	36.7	29.7-44.4	3.0	1.9-4.7
Luapula	Kawambwa	7.3	3.9-13.5	6.8	3.5-13.1	0.5	0.2-1.5
Luapula	Mansa	26.9	19.0-36.5	26.7	18.9-36.3	0.3	0.1-1.3
Luapula	Milengi	50.2	44.8-55.5	50.0	44.7-55.3	0.5	0.1-2.1
Luapula	Mwense	29.2	19.6-41.1	28.4	18.6-40.7	1.3	0.6-3.0
Luapula	Nchelenge	38.5	30.4-47.3	32.7	24.3-42.3	9.2	5.4-15.1
Luapula	Samfya	11.5	8.2-15.8	10.0	7.0-14.1	1.5	0.8-2.9
Lusaka	Chongwe	78.8	65.0-88.1	78.6	64.8-88.0	0.8	0.3-2.6
Lusaka	Kafue	88.6	74.0-95.5	88.4	73.9-95.3	0.9	0.4-1.9
Lusaka	Luangwa	67.8	51.3-80.8	67.8	51.3-80.8	1.7	0.3-7.9
Lusaka	Lusaka	26.2	17.0-38.0	26.2	17.0-38.0	0.8	0.1-5.7
Muchinga	Chama	39.3	27.0-53.2	39.3	27.0-53.2	0.0	0.0-0.0
Muchinga	Chinsali	3.5	1.0-11.3	3.5	1.0-11.3	0.0	0.0-0.0
Muchinga	Isoka	18.5	11.7-28.1	16.5	10.4-25.3	3.3	1.5-7.3
Muchinga	Mpika	26.5	16.3-40.1	21.7	11.9-36.1	5.5	2.6-11.3
Muchinga	Nakonde	1.3	0.6-3.0	1.1	0.4-2.9	0.2	0.0-1.3
Northern	Chilubi	0.0	0.0-0.0	0.0	0.0-0.0	0.0	0.0-0.0
Northern	Kaputa	21.8	14.6-31.2	16.4	10.0-25.7	6.7	4.6-9.6
Northern	Kasama	0.9	0.3-2.3	0.7	0.2-2.2	0.2	0.0-1.2
Northern	Luwingu	0.5	0.1-3.2	0.5	0.1-3.2	0.0	0.0-0.0
Northern	Mbala	3.0	1.4-6.5	3.0	1.4-6.5	0.0	0.0-0.0
Northern	Mporokoso	1.5	0.7-3.3	0.2	0.0-1.2	1.3	0.6-3.0
Northern	Mpulungu	0.7	0.3-1.6	0.3	0.1-1.3	0.3	0.1-1.3
Northern	Mungwi	5.2	1.1-20.9	5.2	1.1-20.9	0.0	0.0-0.0
Northwestern	Chavuma	32.4	20.8-46.5	13.7	8.0-22.6	24.2	14.2-38.1
Northwestern	Kabompo	18.7	14.6-23.6	5.7	3.9-8.2	14.4	10.1-20.1
Northwestern	Kasempa	48.4	41.3-55.6	48.0	41.1-55.1	0.4	0.1-1.5
Northwestern	Mufumbwe	49.0	39.5-58.5	43.9	34.4-53.9	8.6	5.5-13.0
Northwestern	Mwinilunga	29.0	19.4-40.9	27.3	17.7-39.7	2.0	0.9-4.7
Northwestern	Solwezi	11.5	7.2-17.8	10.8	6.5-17.3	0.8	0.3-1.9
Northwestern	Zambezi	49.9	38.5-61.3	34.0	23.2-46.7	24.2	17.6-32.4
Southern	Choma	11.9	7.0-19.5	11.9	7.0-19.5	0.0	0.0-0.0
Southern	Gwembe	16.1	9.3-26.4	3.7	1.2-11.0	13.8	7.5-24.1
Southern	Kalomo	13.1	9.1-18.7	13.1	9.1-18.7	0.0	0.0-0.0
Southern	Kazungula	19.1	9.7-34.2	19.1	9.7-34.2	0.0	0.0-0.0

Province	District	SCH		*S. haematobium*		*S. mansoni*	
		%	CI_{95}	%	CI_{95}	%	CI_{95}
Southern	Livingstone	23.3	16.1-32.5	23.3	16.1-32.5	0.0	0.0-0.0
Southern	Mazabuka	3.8	1.5-9.2	3.8	1.5-9.2	0.0	0.0-0.0
Southern	Monze	2.5	1.2-5.3	2.5	1.2-5.3	0.0	0.0-0.0
Southern	Namwala	14.7	4.4-39.5	14.7	4.4-39.5	0.0	0.0-0.0
Southern	Siavonga	26.2	16.6-38.7	15.5	7.4-29.7	12.7	7.4-20.8
Southern	Sinazongwe	15.4	8.3-26.9	2.7	1.4-5.1	12.9	6.3-24.6
Western	Kalabo	8.8	4.9-15.3	0.2	0.0-1.2	8.7	4.8-15.1
Western	Kaoma	17.6	13.1-23.3	6.8	4.1-11.1	11.0	6.5-17.8
Western	Lukulu	19.2	12.2-29.0	13.2	7.5-22.3	6.9	3.6-12.7
Western	Mongu	2.3	1.1-4.5	2.0	0.9-4.4	0.2	0.0-1.6
Western	Senanga	8.7	3.7-19.0	1.7	0.7-4.0	7.0	2.6-17.5
Western	Sesheke	11.7	4.5-27.1	1.9	0.9-4.0	9.8	3.1-27.0
Western	Shangombo	9.0	4.7-16.6	0.0	0.0-0.0	9.0	4.7-16.6

Appendix 4- Data collection tools

i) Study Site / PCE School Form

Date of visit	(*DD-MMM-YYYY)*	|___|___|-|___|___|___|-|___|___|___|___|	Reporters Initials	|___|___|___|

1. **A. Site Details**		
2. Province (Admin level 1)		
3. District (Admin level 2)		
4. District (Admin level 2) Code	*(DDD)*	|___|___|___|
5. Sub-district (Admin level 3)		
6. Community (Admin level 4)		

B. GPS (at time of…)	
1. Arrival - Latitude	|___|___|___|.|___|___|___|___|___|___|___|___|___|___|
2. Arrival - Longitude	|___|___|___|.|___|___|___|___|___|___|___|___|___|___|
3. Departure - Latitude	|___|___|___|.|___|___|___|___|___|___|___|___|___|___|
4. Departure - Longitude	|___|___|___|.|___|___|___|___|___|___|___|___|___|___|

C. School details		
1. School Name		
2. School Code	*(SSS)*	|___|___|___|
3. Name of Headmaster		
4. Contact Number of Headmaster		

5. Have pupils in your school received deworming treatment in the last year?	*1=Yes* *0=No* *2=Don't know*	|___|
6. Lowest Grade taught	*1=One* *5=Five* *2=Two* *6=Six* *3=Three* *7=Seven* *4=Four*	|___|
7. **Highest** Grade taught	*1=One* *5=Five* *2=Two* *6=Six* *3=Three* *7=Seven* *4=Four*	|___|

D. Enrolment numbers

	Boys Enrolled	**Girls** Enrolled
Total	1. |___|___|___|___|	2. |___|___|___|___|
Grade 1	*3.* |___|___|___|	*4.* |___|___|___|
Grade 2	*5.* |___|___|___|	*6.* |___|___|___|
Grade 3	*7.* |___|___|___|	*8.* |___|___|___|
Grade 4	*9.* |___|___|___|	*10.* |___|___|___|
Grade 5	*11.* |___|___|___|	*12.* |___|___|___|
Grade 6	*13.* |___|___|___|	*14.* |___|___|___|
Grade 7	*15.* |___|___|___|	*16.* |___|___|___|

ii) Study form for pupil

Pupil Form								
	ID Number *(DDD.SSS.NN)*	Sex	Age	Microscopist initials	At least one egg across 2 slides[1]:			
					S. mansoni	Hookworm	Ascaris	Trichuris
1.								
2.								
3.								
	ID Number *(DDD.SSS.NN)*	Sex	Age	Microscopist initials	Urine dipstick result[2]		≥1 egg from urine filtration	
1								
2								
3								

iii) Results Quality control form

ID Number: (DDD.SSS.E.G.NN)* |___|___|___|.|___|___|___|.|___|.|___|.|___|.|___||___|

*DDD – district code, SSS – school code, E – year of entry into the study (0=baseline, 1=first follow-up etc.),

G – school grade at baseline (1=Grade 1 etc.), NN – ID number (00-99)

Quality Control Laboratory Technician Initials: |___|___|___|

A. Kato Katz				
Date *(DD-MMM-YYYY)*	|___|___| |-|___|___| |-|___|___|___|		|___|___| |-|___|___| |-|___|___|	
Slide	*Day 1 Slide A*	*Day 1 Slide B*	*Day 2 Slide A*	*Day 2 Slide B*
Microscopist initials	|___|___|___|___|___|	|___|___|___|___|	|___|___|___|___|	|___|___|___|___|
S. mansoni*	|___|___|___|___|___|	|___|___|___|___|	|___|___|___|___|	|___|___|___|___|
Hookworm*	|___|___|___|___|___|	|___|___|___|___|	|___|___|___|___|	|___|___|___|___|
Ascaris*	|___|___|___|___|___|	|___|___|___|___|	|___|___|___|___|	|___|___|___|___|
Trichuris*	|___|___|___|___|___|	|___|___|___|___|	|___|___|___|___|	|___|___|___|___|

iv) Questionnaire

Department/unit	**Focus area**	**Questions**	**Responses / remarks**
Policy and planning	Health Policy	How many government policies include health? Are NTDs included in the National development plan and health policy?	1=Emergent 2=developing 3=satisfactory 4=strong or full implementation 5=Not applicable (used for all the assessment)
	NHSP	Are NTDs included in the NHSP? Budget allocation	
	NTD Strategy	Is there a national NTD strategy?	

	NTD Information	Are there NTD indicators in the health information system? If yes Which ones? How often are they collected?	
Human resources and administration	MoH structure	How many departments are in MoH	
	NTD Unit	How many officers	
Public Health	programmes	What Programmes are there for NTDs and the status of implementation	
	Partners	Who are the Partners in NTDs	
Finance	Budget	Allocation to NTDs	
Clinical care and diagnostic services	Health Facility treatment for NTDs	Do you have NTD diagnostics and treatment guidelines? If yes for which level(s)?	

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