

MALARIA HYSTERIA: AN INVESTIGATION OF AFRICA'S DEADLY DISEASE
BURDEN AND INTERNATIONAL INTERVENTION

by

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Submitted in partial fulfilment of the requirements
for the degree of Master of Development Economics

at

Dalhousie University
Halifax, Nova Scotia
July 2012

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Dated: July 20, 2012

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DALHOUSIE UNIVERSITY

DATE: July 20, 2012

AUTHOR: Julia Hiscock

TITLE: Malaria Hysteria: An Investigation of Africa's Deadly Disease Burden and International Intervention

DEPARTMENT OR SCHOOL: Department of Economics

DEGREE: MDE CONVOCATION: October YEAR: 2012

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For my grandmother who loved her family unconditionally, who encouraged me to chase my dreams and who, in her own way, made all of this possible.
I love you, and I miss you.

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Abstract

Malaria is a daunting epidemic killing millions of people annually and no region is harder hit than Sub-Saharan Africa (SSA). Each year there are more than 247 million malaria cases in SSA, resulting in more than 600,000 deaths. Despite a comprehensive understanding of the parasite and its transmission, worldwide eradication campaigns have failed to adequately control or eliminate the disease. This paper provides a meta-analysis of historical and current approaches to malaria eradication throughout SSA, highlighting past success and perceived failure to avoid repetitive progression down a path of narrowly focused eradication efforts. Through consideration of the economic costs associated with malaria, as well as a critique of current international elimination strategies, this analysis suggests sizeable and widespread returns to pursuing eradication measures. However, this paper finds that current methods are not sufficient to eradicate the malaria burden and multi-dimensional and all-encompassing approaches are essential to making malaria history.

List of Abbreviations Used

ACT	Artemisinin-Combination Therapy
AIDS	Acquired Immunodeficiency Syndrome
CDC	Centre for Disease Control and Prevention
DALY	Disability-Adjusted Life Years
DDT	Dichlorodiphenyltrichloroethane
HIV	Human Immunodeficiency Virus
IMF	International Monetary Fund
IPT	Intermittent Preventative Treatment
IRS	Indoor Residual Spray
ITN	Insecticide-Treated Net
MDG	Millennium Development Goals
NGO	Non-Governmental Organization
RBM	Roll Back Malaria
RDT	Rapid Diagnostic Testing
SSA	Sub-Saharan Africa
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
USD	United States Dollars
WHO	World Health Organization

Acknowledgements

A simple “thank you” cannot adequately express the gratitude that I feel towards my supervisors Mevlude Akbulut-Yuksel and Ian McAllister, and my reader Owen Willis, for their support, care and guidance throughout this process. I would also like to express my deepest appreciation to my parents, Wade and Sandra, and to my sister, Jennifer, who have always been my greatest supporters - no matter the venture - and who continually face every challenge with assurance, grace and compassion. Without your love and encouragement, none of this would be possible. Finally, to the children of Moshi, Tanzania who continue to influence me daily and who will forever hold a deep and unwavering place in my heart, thank you.

Chapter 1: Introduction

The negative feedback loop between health and destitution is a persistent problem that prevents populations from rising out of poverty, entrenching them with low-income status and perpetual economic stagnation. Poverty related diseases such as HIV/AIDS, malaria, tuberculosis, and cholera contribute to vicious cycles in which low-income countries fall victim to disease traps wherein illness brings about poverty and poverty makes treatment unaffordable and unattainable. Health economists have habitually examined this paradoxical relationship and the results seem conclusive; combatting disease burdens in the developing world is one of the most effective approaches to alleviating poverty and stimulating economic growth (Gollin and Zimmerman, 2007; Miguel and Kremer, 2004; UN, 2011; UNAIDS, 2011; WHO, 2011).

It is widely acknowledged that sub-Saharan Africa (SSA) is host to many of the world's poorest countries and most deprived populations¹. Not so well established are the precise reasons for which SSA is perpetually laden with low-income status. Naturally, there is no single explanation for SSA's sluggish pace in comparison to the developed world, but there are key factors that contribute to its hindered growth and deterred development. An explanation that is fundamental to this paper concedes that SSA houses some of the most infectious and morbid disease burdens. HIV/AIDS is the leading cause of adult mortality in the region, accounting for more than 1.3 million deaths annually (UNAIDS, 2009). Tuberculosis prevalence is increasing cyclically with HIV and was recently deemed a public health emergency throughout most of SSA (WHO, 2010). Most alarmingly, malaria is endemic in 42 African countries with an estimated 250 million cases annually and it is the primary cause of death in children under the age of five (WHO, 2010). To further emphasize these sizeable statistics, over 72 percent of African fatalities result from communicable diseases, the majority of which are treatable (WHO, 2010). SSA's disease burden is far from revolutionary and evidently has been the focus of substantial public health and economics research. Why then do treatable diseases, such

¹ Despite having strong GDP growth in the last decade (averaging 5.7% per year since 2001), GDP per capita remains exceptionally low at approximately 6% that of advanced economies (Figure 1 and 2).

as malaria, continue to threaten the region? Perhaps the answer to this question is embedded in modern approaches to control, treat and prevent disease burdens.

Malaria has become a worldwide phenomenon in its global terrorization of unsuspecting populations. From symptom expression to research and development, global eradication pursuits to epidemiological discoveries, malaria continues to be met with some degree of hysteria. Alarm at the diagnosis and often-untreatable reality of malaria, as well as global efforts to eliminate the disease, have garnered unprecedented support and overwhelming expressions of frenzy. Be it rage at the poverty and inequality related to the disease burden, disappointment at historical eradication failure, or overstated optimism as we once again attempt to annihilate the pesky parasite, malaria has become inescapable in its universal perseverance. We all want malaria's reign of trepidation to end. The recurrent and widespread malady and deprivation associated with the disease burden has been incomparable to any other global pandemic validating populations' panic related to its manifestations and eradication. As we wait with baited breath to observe the outcome of the most recent global stance against the deadly parasite, hope still lingers to avoid the plunge into the same disillusionments that plagued us nearly forty years ago. However, unless past eradication efforts are reconsidered in earnest, the hysteria associated with malaria morbidity, treatment, and prevention may continue indefinitely.

In addition to raising awareness about the malaria epidemic, this paper will review historical and current approaches to malaria eradication, and propose a collaborative approach to prevention and treatment of the debilitating disease, taking into consideration lessons learned from past successes and perceived failures. Malaria has been a highly publicized disease for decades, and arguably centuries, yet unsubstantial eliminatory progress has been made in the SSA region. Frequently referred to as a "tropical disease", malaria continues to take an extreme social, medical, and economic toll on the lives of millions of people worldwide. Without doubt it is time for malaria to join an elite group of extinct illnesses since, for the first time in history, we have the knowledge, commitment, and cooperative tools necessary to make this dream a reality. I commence with a brief review of the magnitude of the malaria epidemic in SSA and the

various channels through which the epidemic influences economic prosperity and development. I continue with a valuation of the costs and benefits associated with worldwide malaria eradication strategies, concluding with a discussion of multi-level responsibilities, policy implications and potential next steps as we continue our global fight against malaria.

Chapter 2: Malaria Epidemic

2.1 Statistics and Prevalence Rates

Globally, there are more than 247 million cases of malaria annually and each year approximately 655,000² people die as a result of the raging epidemic. Shockingly, over 90 percent of these deaths occur in SSA (RBM, 2011). Malaria kills one in five African children, essentially stealing the life of an African child every 30 seconds (RBM, 2011; UNICEF, 2005). These are examples of shocking statistics publicized daily by public health, and government policy workers. What is not often revealed is that more than 3.3 billion people are at risk of contracting malaria. Figure 3 shows global populations at risk of contracting malaria. Of the 109 countries in which the disease is endemic, 35 of the 47 countries in SSA account for nearly 98 percent of worldwide malaria fatalities (RBM, 2011). Figure 4 shows malaria related death rates throughout SSA. Furthermore, the sheer size of this epidemic is perhaps best highlighted in comparison to other global tragedies. On September 11, 2001, close to 3000 people were killed in the haunting New York City terrorist attack. Holocaust death tolls range in the vicinity of 10 to 20 million victims, World War I is estimated to have taken approximately 20 million lives throughout five years of battle, while World War II claimed around 60 million lives over six years. In fact, malaria kills twice as many people as are living in the Halifax Regional Municipality every year. Astonishingly, aggregated over time, malaria has claimed more victims than every war and plague throughout history, combined.

In SSA, malaria constitutes an estimated economic liability of more than 12 billion USD per year (RBM, 2011; WHO, 2010). Comparably, Gallup and Sachs (2001) estimate that the economic cost of malaria can exceed one third of annual GDP in a region hard hit by the epidemic. Figure 5 shows the global geographical distribution of malaria over time, and Figure 6 reports global values of GDP per capita in 1995 dollars.

² The World Malaria Report estimates that between 537,000 and 907,000 people died as a result of malaria in 2010 alone; 655,000 is simply a weighted average of these estimates.

These figures present a stark illustration of the correlation between geography, disease and economic prosperity.

Most of SSA is situated within tropical eco-zones with warm temperatures and long rainy seasons, which, unfortunately represents an ecological combination similar to that of a double-edged sword. On one hand, this paradisiacal climate is what tourists around the world seek; on the other hand this tropical climate facilitates the breeding requirements of numerous parasites and infections. Specifically, much of SSA ecology sustains a thriving breeding ground for malaria transmission, which is substantially more apparent in developing regions surrounding the equator (Sachs, 2003). As time progresses, we approach the possibility of controlling and even eradicating malaria worldwide. However, it is imperative to better understand the social, ecological, medical and economic implications of malaria in a context specific manner in the pursuit of bringing this dream to fruition. Understanding how malaria is transmitted is essential to achieving this goal. As is discussed in the following section, the epidemiology of malaria is quite deceiving given its complex requirements, yet widespread prevalence.

2.2 Epidemiology

Malaria is the common name for a potentially deadly parasite of the Plasmodium genus that is transmitted by mosquitoes in tropical regions (RBM, 2011; WHO, 2011). Malarial infections require the presence of female Anopheles mosquitoes³ that disperse the Plasmodium parasite from person to person via their blood stream. Anopheles mosquitoes are selective in that they require precise tropical ecosystems with warm temperatures, abundant rainfall and high levels of humidity. Lucas (2006) reports that temperatures of at least 18 degrees Celsius, land elevation of less than 2000 meters, and more than 2000 millimetres of annual rainfall are required to sustain the mosquito. In addition, anopheles are nocturnal, only engaging in feeding behaviours after sundown. Mosquitoes thrive in stagnant water sources such as small lakes, puddles, and roadside

³ Female anopheles mosquitoes feed on human and animal blood because they require substantially high energy levels for physical development and reproduction (Packard, 2007).

ditches making it possible for them to thrive anywhere, therefore increasing the difficulties associated with chemical elimination methods.

When the Anopheles mosquito feasts on human blood the Plasmodium enters the individual's plasma in the form of a sporozite⁴ and moves towards the host's liver. There, the sporozite undergoes a number of complex mutations, forming cells called merozoites which take approximately 5 to 6 days to mature before entering and attacking the host's red blood cells (Gollin and Zimmerman, 2007; Packard, 2007; RBM, 2011). In the absence of treatment, the parasite continues to destroy red blood cell immunity, often leading to the development of cell anemia and, in severe cases, death (RBM, 2011). Since the parasite is most infectious during this initial period of blood cell destruction, it is important to detect and treat the parasite within two weeks following infection before rapid spreading of the parasite can occur (Gollin and Zimmerman, 2007; RBM, 2011). The parasites continue to grow and multiply by feasting on the host's hemoglobin, while slowly travelling throughout the blood stream. The merozoites then differentiate into male and female species called gametocytes, which are transferred to other anopheles mosquitoes during a blood meal⁵ (Packard, 2007).

Inside the new mosquito, the gametocytes undergo sexual reproduction and produce new sporozites, which are deposited in the mosquitoes salivary glands and then released into a new human host upon the mosquito's next feeding; this completes both the asexual and sexual reproduction cycles. According to Packard (2007) each cycle of parasitic reproduction can increase the parasite count by up to 16 times the previous population. It takes approximately 10 to 14 days for symptoms to appear in the new human host (RBM, 2011). Figure 7 provides a graphic depiction of the malaria parasite transmission cycle.

⁴ A sporozite is the name for the malaria parasite when it first infects human hosts. They are developed in mosquito salivary glands and deposited into the host's blood, ending in the liver where the sporozite undergoes several mutations and approaches maturity.

⁵ A "blood meal" simply refers to the feeding of an anopheles mosquito on human blood; the act of the mosquito biting the human host.

As is evident in the brief biological explanation provided above, the breeding and transmission of a malaria parasite is not a simple phenomenon. To further emphasize the complexity of malaria transmission, the female anopheles mosquito has a life expectancy of only 10-21 days, which according to Packard (2007) provides barely enough time to complete the reproduction cycle.

There are four classes of Plasmodium parasites acquired by humans; Plasmodium Malaria, Plasmodium Ovale, Plasmodium Vivax and Plasmodium Falciparum. RBM (2011) notes that Vivax and Falciparum are the most common strands of the virus, but that the latter is by far the deadliest parasitic specie. The extreme differences between these four forms of Plasmodium result from their varied reproduction cycles. Plasmodium Malaria, Ovale, and Vivax attack only the host's red blood cells (as described above). However, Plasmodium Falciparum attacks *all* of the host's blood cells, and typically results in severe morbidity, or mortality. The first three classes of Plasmodium parasites cause long and recurrent symptoms, while the fourth, most dangerous specie of Plasmodium, results either in short-term side effects, or death (Packard, 2007). Unfortunately it is Plasmodium Falciparum that is most common throughout much of SSA, which further attests to the abundance of malaria fatalities in this region. The prevalence of each of these parasites leaves millions of Africans susceptible to its destructive implications. Figure 8 shows SSA populations considered to be at risk of contracting malaria.

Initial indications of malaria resemble flu-like symptoms including extreme fever, tremors, fatigue, nausea, vomiting, chills, and muscle pain and can last up to two months. However, within days of contracting the parasite symptoms may progress to life threatening conditions such as anemia, respiratory distress, seizures, coma, hypoglycemia, jaundice, kidney failure, and cerebral malaria⁶ (Lucas, 2006; WHO, 2010). Cerebral malaria, the most deadly and damaging manifestation, occurs when the Plasmodium parasite blocks the capillaries that transfer blood to the brain and surrounding organs frequently leading to rapid death (RBM, 2011). Plasmodium parasites

⁶ Cognitive malaria is defined by Holding and Snow (2001) as any form of coma-induced malaria.

usually remain active in the human blood stream for approximately 64 days; however, the parasite may lay dormant in a host's liver for a several months or years with reinfection occurring sporadically (Gollin and Zimmerman, 2007; Kitua et al., 1996).

Admittedly, the above discussion of malaria transmission is by no means comprehensive. However, it does attest to the complex transmission mechanism that underlies the malaria parasite and highlights several fundamental complications associated with preventing, treating, and eradicating the epidemic. Malaria is not an easily transferable disease, it requires the presence of malarial parasites and female anopheles mosquitoes, it must survive four distinct life stages before human infection is possible, and it requires specific climatic conditions. Similarly, malaria often depends upon reduced immune system efficiency, ill health and inadequate sanitation conditions. SSA, more than any other continent, exhibits the ruinous combination of these elements.

2.3 Susceptible Populations

Malaria is not a selectively infectious disease; it can occur in any person, of any age or race, regardless of their gender. However, the probability of contracting severe and destructive side effects is most amplified in childhood and diminishes with age, especially in regions severely stricken by poverty. As Lucas (2006) suggests, the individuals most at risk for acquiring malaria are those with the frailest immune systems, typically pregnant women and children. Kitua et al. (1996), report positive indications of the Plasmodium parasite in 5.3 percent of infants at five days old, and estimate a childhood malarial infection rate of 2.1 episodes per child. Unfortunately, through placental transmission, maternal malaria during pregnancy can increase the probability of infantile infection and can result in infant mortality or impeded future health and human capital endowments (Gollin and Zimmerman, 2007; Ter Kuille, 2004). However, mothers can also transmit Immunoglobulin G, a protecting antibody, through the placenta that may help infants avoid severe malaria infection in the first few days of life (Kitua et al., 1996).

UNICEF (2005) estimates that 20 percent of child fatalities in SSA result from malaria. Many of these deaths are perpetuated by the development of cerebral malaria

following recurrent infection. In SSA alone, this deadly form of malaria affects more than 785,000 children annually (Chady et al., 2008). Kitua et al. (1996) examine malaria infection rates in Tanzania and find that 10.5 percent of child cases mature to cerebral malaria; this is substantially higher than the proportion of adult patients who suffer from the deadly disease. Chady et al. (2008) find that cerebral malaria results in severe cognitive impairments in 25 percent of survivors. As will be discussed in Chapter 3, childhood malaria can also lead to cognitive impairments, which decrease educational attainment and future labour market outcomes. Since childhood development is a precursor to future health status and cognitive abilities, we must find a way to protect children from the harmful consequences of malaria.

Women are also disproportionately susceptible to health complications associated with malaria. Intuitively, the most destructive malaria symptoms occur during pregnancy, when maternal immunity is suppressed. Pregnant women infected with malaria have significantly higher risks of developing cell anemia⁷, which can disrupt the nutrient flow between mother and fetus, potentially endangering both woman and child (Gollin and Zimmerman, 2007; Lucas, 2010). In addition to anemia, maternal malaria during pregnancy often leads to a multitude of harmful infantile side effects including physical and cognitive deficits, low birth weight, shorter gestation, learning impairments, and delayed neurological development (Barofsky et al., 2011; Duffy and Desowitz, 2001, as cited in Lucas, 2010; Lucas, 2010; WHO, 2010). For instance, McGregor (1984, as cited in Lucas, 2010) finds that maternal malaria prevalence during pregnancy corresponds to an average reduction in infant birth weight of 0.6 to 1.5 pounds, an important statistic given that low birth weight is highly correlated with reduced school performance and lower educational attainment (Holding and Snow, 2001). Previous literature attests to the importance of maternal health with respect to prosperous childhood development, human capital accumulation, and economic prosperity (Almond and Currie, 2010; Golin and Zimmerman, 2007; Kitua et al., 1996; Ter Kuile et al., 2004).

⁷ Anemia is a hemoglobin deficiency involving the destruction of red blood cells, which limits oxygen flow throughout the body.

Public policy and eradication campaigns often concentrate on the most susceptible populations in order to limit the health and economic hardships associated with the malaria endemic. For instance, the recent RBM campaign has made an effort to prevent malaria infection during pregnancy, to increase the proportion of children under five protected by insecticide-treated nets (ITNs), and to ensure that children are promptly treated for fever-related symptoms. Given this basic overview of the malaria epidemic, I now highlight some of the economic costs of malaria before proceeding to a discussion of malaria treatment and eradication methods.

Chapter 3: Economic Costs of Malaria

The malaria disease burden faced in SSA is one of the most damaging and destructive pandemics in the world. The following is a short summary of several broad implications of the epidemic; not all are necessarily targeted through malaria control or prevention programs. Each of these mechanisms shows the depth of the malaria epidemic and the widespread impediments associated with the disease. However, as will be discussed in Chapter 4, there is light at the end of the gloomy malaria tunnel; malaria is a *treatable* disease, and we have never been more equipped to eliminate this grave burden.

3.1 Macroeconomic Implications

3.1.1 Economic Growth

One cannot logically conclude that malaria is the sole reason SSA finds itself in a poverty trap. However, according to RBM (2011), malaria presents the region with an economic burden of more than 12 billion USD annually. Gallup and Sachs (2001) estimate the economic cost of malaria at approximately one third of annual GDP in hyper-endemic malaria regions. McCarthy, Wolf, and Wu (2000) find that SSA regions experience a 0.55 percent reduction in income growth due to its malaria disease burden, and after controlling for an array of exogenous variables including health, income and geography, Gallup and Sachs (2001) report that malaria accounts for 1.3 percent of annual growth loss in SSA. Similarly, the authors estimate that a 10 percent increase in malaria reduction strategies is correlated with a 0.3 percent higher growth rate in the analogous time period. Furthermore, between the late 1960's and 2000 malaria prevalence in SSA increased by 50 percent while the region saw a corresponding decline in GNP of more than 40 percent in the same time period (Packard, 2007). These numbers become quite large when aggregated over the entire African continent. Despite billions of dollars spent on eradication campaigns, very little has changed with regards to the segregating effects of malaria control and prevention; it is still very much a poverty-

related disease. The apparent inability of SSA economically to “grow out of malaria”⁸ presents a major challenge for future projects.

In his 2010 paper, Weil investigates the economic impacts of malaria on development in SSA prior to European colonization. Using knowledge of the malaria combatant effects of hemoglobin S⁹, Weil (2010) finds that malaria prevention was less of a health burden five centuries ago. The author suggests that severe malaria morbidity and mortality increased significantly following the arrival of European settlers who lacked acquired malaria immunity, therefore propagating the growth-deterrent effects of malaria.

In SSA, malaria accounts for more than 40 percent of inpatient and outpatient admissions, and constitutes significant costs to local governments and aid organizations (RBM, 2011). Figure 9 shows national percentages of SSA populations treated as inpatient malaria case. Ettlign and Shepard (1991) estimate that the Rwandan government spends over 18 percent of its allocated health-care expenditures solely on treating malaria patients, and Rwanda is certainly not an outlier in this regard. However, RBM (2011) argues that 90 percent of African governments spend only 15 percent of health care budgets on malaria control, which further perpetuates the poverty trap related to the disease. Due to stark budget constraints, most endemic regions cannot contribute enough funding to cover malaria expenditures, leaving prevention and eradication dependent on vast international support.

Not only is malaria a root of increased medical costs, and forfeited economic growth, it also affects international investment opportunities and the decisions of foreign donors. Investors are less likely to travel to or invest in prospects located in a region

⁸ Packard (2007) often refers to a country’s ability to “grow out of malaria” as economic development leading to a decline in malaria infection rates in a given region due to an improvement in social and economic conditions.

⁹ Hemoglobin S is a mutation of normal human hemoglobin. When two hemoglobin S molecules are inherited an individual acquires sickle cell disease, however when one only is acquired it has protected properties against malaria falciparum, without causing sickle cell disease. In this way people with sickle cell trait hemoglobin have additional protection from malaria beyond those with normal hemoglobin.

laden by progressing disease burdens (RBM, 2011). In addition, tight household budgets can result in reduced precautionary savings in malaria endemic regions. Bhattacharya (2009, as cited in Bleakley, 2010) examines savings in several SSA countries and finds that regions with low malaria prevalence save more and receive more foreign direct investment facilitating a growth potential to rise out of poverty. Both directly and indirectly, malaria is hindering development opportunities in SSA at a significant pace. Malaria also indirectly affects economic growth by limiting educational attainment, increasing morbidity and infant mortality and absenteeism, deterring tourists, and discouraging labour-intensive production. Each of these will be considered in subsequent sections.

3.1.2 Poverty and Well-Being

Chima et al. (2003) report that the world's richest 31 countries are malaria free, while 108 of the world's 120 poorest countries are experiencing vast malaria epidemics, including 35 African nations. In addition, 58 percent of global malaria cases occur in the poorest 20 percent of the world's population, making malaria an incontestably poverty-related disease burden (Barat et al., 2004). Figure 10 shows a geographical depiction of the relationship between the global malaria burden and poverty rates worldwide.

There is significant debate as to the direction of this correlation, as some researchers believe malaria is a result of characteristics of poverty that facilitate opportune transmission including poor sanitation, infrequent access to health care, untreated water systems, conflict, lack of infrastructure, and inadequate nutrition. It comes as no surprise that countries in SSA perpetually fall victim to each of these claims. In this view, poverty makes timely protection against and treatment of malaria unmanageable. Healthy populations require access to medical treatments and health education programs, as well as a balanced diet to prevent and combat illness and disease. Sadly, this is not always attainable for the poorest populations, given that malaria typically exerts disproportionately devastating effects on individuals living in poverty. However, others believe that the malaria epidemic itself causes extreme levels of poverty through physical illness, labour loss, high medical costs, as well as the incessant risk of reinfection. Amidst the debate, one thing is clear; SSA will continue to face unforgiving

poverty while malaria is endemic. It is essentially an impossible feat to disentangle improvements in socioeconomic conditions resulting from malaria reductions from those related to other global development initiatives. For instance, efforts to improve sanitation conditions, promote clean drinking water, and provide adequate nutrition will all help to reduce malaria transmission rates in SSA. This once again highlights the importance of viewing malaria as a social disease, closely related to poverty. Nevertheless, due to this complex relationship, malaria can unfortunately be blamed for many poverty implications that are not necessarily warranted.

Poverty and malaria converge significantly throughout episodes of civil war and armed conflict throughout SSA, indicative of their complex relationship (Packard, 2007). Additionally, malaria is a leading cause of death in SSA refugee camps that often experience disproportionately high levels of poverty and destitution. According to Packard (2007) only four of 43 countries experiencing internal conflict are free from the malaria burden. These statistics show the degree to which malaria flourishes in poverty-stricken regions, slowly diminishing the wellbeing of millions of individuals worldwide.

Disability Adjusted Life Years (DALY) is the common economic measure of disease burdens summing averted years of illness, severe disability, and premature morbidity. It was developed for the World Bank in the 1990s to more accurately quantify the consequences of poor health on global citizens. Today the World Health Organization (WHO) often reports DALYs in its analysis and estimates that malaria in SSA accounts for 35.4 million DALYs. This means that if malaria ceased to be endemic in SSA there could be 35 million disability-averted life years. The economic costs per DALY in this region are typically low and will be considered further in Chapter 4.

3.1.3 Production and Labour Supply

The intense side effects of malaria cause frequent and often prolonged absenteeism from workplace employment and/or educational institutions. Chima et al. (2003) estimate the labour cost per adult between one and five days per malaria episode. This is a prominent concern given the previously discussed rapid reinfection rates. Absenteeism can be further propagated when infected children miss school and adults are

required to decrease their labour supply to provide care for the children (and potentially, vice versa). Chima et al. (2003) value this decrease in annual labour supply at approximately 10 labour days lost per child.

In a unique longitudinal experiment, Hong (2011) suggests that the labour productivity loss associated with malaria in the United States is much more pronounced than was originally estimated. Hong (2011) claims that once infected with malaria, labour productivity does not return to its initial levels due to extreme levels of malnutrition, susceptibility to reinfection, and weakened immune systems, and postulates that labour productivity could be hindered for decades following a rise in malaria prevalence. In SSA, Leighton and Foster (1993) estimate a similar production loss associated with malaria at approximately five percent in Nigeria and between two and six percent in Kenya.

The production and labour consequences of malaria are best illustrated given a historic example. Gallup and Sachs (2001) reiterate the malaria endemic present in Panama during the late 1890s and early 1900s and the economic impact of the disease burden on infrastructure and labour supply. Unfortunately, due to the debilitating side effects and the rapid transmission of malaria, well over 200,000 construction workers lost their lives in a nine-year attempt to complete the Panama Canal (McCullough, 1977, as cited in Gallup and Sachs, 2001). As death tolls soared, construction of the magnificent water way came to a halt. As Gallup and Sachs (2001) contest, it was not until years of malaria prevention, treatment, and eradication methods were established that the Panama Canal was finally completed in 1914. Clearly, malaria is not a *new* health concern, and it has been playing a deterministic role in infrastructure provision and economic development for centuries.

Similar to the scenarios described above, malaria prevalence has the power to influence household decisions, which may hinder economic progress in SSA. For instance, business owners and farmers may elect to produce using laboursaving technology to avoid the increased absenteeism so often associated with malaria (RBM, 2011). Not only does this decrease labour demand but it also limits product variation. While adopting newer, more efficient technologies can be a critical contribution

economic development, in a region with an abundant, low cost labour force this can also give rise to poverty and destitution for millions.

3.1.4 Tourism

Tropical diseases such as malaria can also inhibit tourism. In a country such as Tanzania or Kenya, where thousands of tourists flock each year to avail of the beautiful landscapes of the Serengeti, or to climb majestic Mount Kilimanjaro, malaria can be a monumental deterrent as tourists are reluctant to visit areas experiencing a deadly pandemic. Ignorance as to the transmission and severity of malaria can make international travelling an unnerving endeavour and malaria prevention medications are often expensive, even by high-income standards. In addition, preventative medications can be accompanied by severe side effects, which can deter travellers from embarking on adventure to a hyper-endemic region. This loss of international tourists can be quite sizeable and can have significant economic impacts on an entire region¹⁰.

3.2 Microeconomic Implications

3.2.1 Neuroscience and Cognition

In addition to the aforementioned physical and economic side effects associated with malaria, cognitive deficits related to the epidemic have recently received attention in Psychology and Neuroscience research. During the first year of life neuronal connections flourish in the central nervous system and active synapses are enhanced as the frontal lobe begins to mature, making malaria symptoms the most cognitively damaging in early childhood. For instance, Barofsky et al. (2011) propose that infants infected with malaria may suffer irreversible cognitive impairments including diminished short and long-term memory, hypoglycemia, depressed socio-emotional functioning, slowed visuo-spatial and motor skills, impeded language development and comprehension, as well as impaired attention capabilities. Holding and Snow (2001) propose that the most damaging cerebral

¹⁰ In my own travels, I met several travelers who prematurely ended their trips after a diagnosis of malaria. They returned home, leaving their adventures and scenic tours, safaris, and spice islands, unexplored.

impacts of malaria occur between the first six months of life and seven years of age. This critical period precedes the development of cognitive functions such as organization, self-awareness and social decision-making, all of which play a central role in adolescent and adult success. This neurological damage can also impair a child's speech, hearing, sight, and muscle control while also emphasizing behavioural disorder and social awareness (Holding and Snow, 2001). Given the lasting impact that cerebral malaria has on cognition, the damaging effects of malaria with respect to human capital accumulation and social development become evident.

As was discussed previously, cerebral malaria is a life-threatening disease that hampers the central nervous system, impacts cognitive functioning and alters typical neurological development (Gollin and Zimmermann, 2007; Holding and Snow, 2001). Due to the pivotal importance of undisrupted development during the first few years of life, cerebral malaria has the most long-lasting and pronounced ramifications in early childhood. Cerebral malaria leads to irreversible impairments and rapid death. Chima and colleagues (2003) estimate that approximately 16 percent of patients who survive cerebral malaria are left with neurological impairments lasting upwards of six months. Similar statistics are found by John et al. (2008). Seizures originating in the temporal lobe are reported in 85 percent of patients suffering from cerebral malaria; malaria associated epilepsy is highly correlated with several psychological and behavioural maladies (Holding and Snow, 2001). Unfortunately, in many parts of SSA, seizures that result from malaria can be attributed to religious, supernatural, or magical impositions (Chima et al., 2003). If these beliefs cause children to be untreated the chances of suffering severe morbidity or mortality increase substantially. This example highlights the importance of simultaneous educational awareness about the epidemiology of malaria, its side effects and available treatments, especially in the developing world. In addition to educating SSA populations about the complications associated with malaria, we must also strive for a shared understanding of the mental illness and neurological impairment that accompanies the disease. When a child suffers the neurological or psychological side effects of malaria they often require additional care to foster development. Of course, this engages a second person to care for the child and household income can be even further diminished.

3.2.2 Human Capital Accumulation

Traditionally, human capital investment attests to the decision of individuals to maximize income throughout their lifetime by choosing an appropriate level of education. However, this is not always the case in the developing world, especially for the most vulnerable families at the bottom of the income distribution (Almond and Currie, 2010). Many individuals, especially children, do not *choose* their own level of human capital investment; rather they avail of the accessible resources serviceable in their specific household. Human capital “investment” often infers a choice in which an individual maximizes lifetime income by investing in education until the marginal costs exceed the marginal benefits. Contradictorily, human capital “accumulation” accounts for situations in which poverty, or socioeconomic conditions, interrupt this precise investment decision. Throughout this paper, I will refer to human capital accumulation rather than specifically adhering to the human capital investment decision.

Bleakley (2010) suggests that health is both a form of human capital as well as a channel through which we acquire other varieties of human capital such as education, vocational skills, workplace training, and employment. For several reasons, unhealthy populations typically limit their accumulation of human capital. First, malaria infections can decrease life expectancy and increase morbidity, which can limit human capital accumulation and productivity. Second, people invest more in human capital throughout childhood and adolescence if they are unlikely to be hampered by disease burdens in adulthood (Bleakley 2010). According to Jayachandran and Lleras-Muney (2009), this longer life expectancy fosters incentive to invest in human capital and reap the benefits of additional schooling. The authors find that a rapid and dramatic increase in life expectancy in Sri Lanka in the late 1940s led to substantial increases in literacy and years of schooling (Jayachandran and Lleras-Muney, 2009). Intuitively, this theory suggests a sizeable impact on human capital investment decisions for individuals living in the developing world where up to 40 percent of the population is at risk of acquiring a communicable or life-threatening disease (RBM, 2011). The effects of malaria on human capital accumulation have been well established in previous literature, with little

dispute¹¹. It seems intuitive that children suffering from severe and/or frequent malaria infections will have decreased school attendance, and lower educational attainment due to the child's ill health or family income constraints.

It is well established that most human capital is accumulated throughout childhood and adolescence. This means the time in which individuals are most susceptible to malaria, when cognitive development is most critical, and when human capital is acquired overlap significantly. This further increases the detrimental effects of the malaria disease burden. Unfortunately, it is often difficult to acquire effective micro data regarding the timing and recurrence of malaria infection and children's school attendance, or workplace training. However, authors such as Barreca (2010) have developed unique and pivotal ways to attest to the causality of this relationship. In his seminal paper, Barreca (2010) finds that child cohorts born in unseasonably warm and wet years (which foster malaria transmission) typically have lower educational attainment than those born in colder drier seasons. Brooker and colleagues (2000) report that African students typically miss between 3 and 8 percent of their school year due to malaria. Likewise, Leighton and Foster (1993) investigate time lost due to malaria in Kenya and find that children miss more than 11 percent of the school year due to malaria-related absenteeism, and malaria accounts for half of all preventable school absenteeism in SSA. Barofsky et al. (2011) find a negative correlation between malaria and educational attainment in Uganda and postulate that the benefits of malaria eradication translate to three percent of annual income due to increased literacy and school attendance. Similarly, the authors find that malaria reduction results in an eight percent increase in educational attainment (Barofsky et al., 2011). Lastly, Lucas (2010) investigates the effects of malaria eradication on human capital in SSA and finds that increasing malaria eradication efforts by 10 percentage points increases children's literacy by one percent and school attendance by almost one month per year, a substantial increase given that the average years of schooling in SSA are amongst the lowest in the world.

¹¹ Acemoglu and Johnson (2005) claim there is no statistically significant improvement in educational attainment as a result of malaria eradication campaigns.

3.2.3 Household Budget Constraint

Individuals living in SSA are often subject to modest living conditions, poor sanitation, and ill health. This of course can perpetuate frequent malaria infections through reduced immune system responses. However, as was previously discussed, the high costs associated with malaria prevention and treatment can also be seen as a cause of poverty and low-income status. Lucas (2010) suggests that children not personally infected by malaria can be hindered by the decrease in household income that is associated with treating the disease. Simply put, the costs associated with malaria often prominently reduce family income leaving fewer financial resources available for necessities such as schooling, nutrition, and shelter.

Chima and colleagues (2003) review existing literature concerning the economic implications of malaria and define direct costs as household and governmental expenditures on malaria prevention and treatment including bed nets, insecticides, medications, doctors visits, and education programs. The authors value such methods at between \$1.88 to \$26 US per family. Nonetheless, these expenses are not easily funded, given that millions of African citizens are still living below the \$1.25 per day poverty line. Ettlting and colleagues (1994) estimate the cost of malaria prevention and treatment to be approximately 28 percent of household income, imposing substantial medical costs, which restrict household spending.

The daunting household costs of malaria can also lead to resource splitting and discriminating decisions regarding human capital investment; often, one child is favoured with regards to educational attainment and an emphasis is placed on quality of children's education versus the number of children actually enrolled in schooling programs (RBM, 2011). Similarly, one child may be allowed to attend school while others are required to participate in the labour force to contribute to household income. From a divergent vantage point, malaria can also impact fertility as child mortality related to the epidemic could perpetuate precautionary fertility behaviour. These examples certainly do not constitute an exhaustive list of the externalities associated with malaria, they are discussed solely to highlight the extent to which malaria is affecting the decisions of individuals around the world.

3.2.4. Intergenerational Transmission

In recent years, theories regarding the intergenerational transmission of attributes between parents and children have received significant attention. Almond (2006) found that children of mothers infected with influenza during the epidemic of 1918 were 15 percent less likely to complete secondary school and were likely to receive lower wages in adulthood than children whose parents escaped the epidemic. DeLange and West (2003, as cited in Bleakley, 2010) find that administering iodine supplements to women during pregnancy is associated with an increase in children's IQ by five points on standardized tests. Jayachandran and Lleras-Muney (2009) find that in Sri Lanka, each one year decline in maternal mortality increases children's literacy by two percent and years of schooling by three percent. Of keen interest to this paper, Duffy and Desowitz (2001 as cited in Lucas, 2010) find that children of mothers, who become infected with malaria while pregnant, exhibit deficiencies in cognitive, physical and neurological development, which is likely to alter the child's educational capabilities. As was discussed in Chapter 2, maternal malaria during pregnancy can lead to a multitude of harmful side effects including physical and cognitive deficits, learning impairments, delayed neurological development, and low infant birth weight (Barofsky et al., 2011; Duffy and Desowitz, 2001, as cited in Lucas, 2010; WHO, 2010). Since childhood development is a precursor to future health status and cognitive development, we must find a way to protect children from the harmful consequences of malaria. Due to limited micro data sources referencing malaria in the SSA region, this topic continues to showcase a direction for future research quantifying the neglected consequences of the malaria epidemic.

Chapter 4: Eradication Methods

4.1 A Short History of Malaria Eradication

Malaria is a daunting health concern that has captured the attention of researchers for centuries. Packard (2007) estimates that the origins of the malaria parasite date back half a billion years. Malaria is considered to have led to the demise of Alexander the Great in 323 BCE (Cunha, 2004). Similarly, Packard (2007) cites examples of the ancient philosopher, Hippocrates, dealing with symptoms of malaria in ancient Greece suggesting that in 413 BCE, malaria played a pivotal role in the battle of Syracuse. There are similar documentations of Roman cardinals dying as a result of mal-aria (bad air) in the 1600s (Packard, 2007). In the 19th century, scientists including Alphonse Laveran, Ronald Ross, and Giovanni Grassi made significant progress in understanding the complex transmission of the malaria parasite (Packard, 2007). In the 20th century, Italian malariologist Angelo Celli published a seminal book recognizing, the precise role of the anopheles mosquito in malaria transmission (Packard, 2007). Contrary to ancient approaches to the epidemic, each of these discoveries led to an emphasis on biological and medicinal treatment of the disease, without an imperative focus on the broader, more social implications of the disease burden. Furthermore, malaria has been a prominent health concern for centuries and given recurring eradication efforts, it is disconcerting that we have not yet achieved substantial eradication.

Prior to this century, malaria was not considered a predominantly tropical phenomenon, as countries worldwide were experiencing the destructive effects of this disease burden. Although malaria is suspected to have originated on the plains of Africa, by the 1800s, it spread north and was even endemic in the United States (Packard, 2007). However, as time progressed and treatment and prevention methods were engineered, the disease slowly became a poor man's burden, as those in low-income brackets were unable to afford, or access, the preventative technologies necessary to obstruct the mosquito's reign. Initially, this income segregation was apparent within countries. Low-income families living on plantations or farms were typically not able to migrate from

malaria-infected regions or mosquito breeding grounds and were continually exposed to the daunting side effects of the disease. Similarly, wealthy American farmers were often able to pay workers to maintain farm grounds near swamps and malaria breeding sites so as to avoid malaria infection (Packard, 2007). These inequalities in susceptibility became increasingly evident between nations.

Malaria eradication methods have seemingly undergone cyclical transformations within the last century. Packard (2007) suggests that throughout the 19th century, prior to epidemiological breakthroughs, disease burdens were seen as having social origins and malaria was treated as such; with an emphasis on improving living conditions and refining health practices. Unfortunately, over time the emphasis placed on the socioeconomic conditions in which malaria is transmitted has dwindled and has taken a back seat to whichever new control or treatment strategy is deemed appropriate at the time. This perpetually recurrent cycle is discussed below.

Black (1986) suggests that worldwide eradication strategies first became apparent following successful malaria control during the final construction of the Panama Canal in 1914. Throughout the initial building of the canal, labour supply was severely diminished due to the debilitating side effects of malaria. It was to eliminate this burden that workers began a multifaceted effort to prevent the breeding of mosquitoes near the construction site. Recognition of the role of water sources in malaria transmission led to strategies such as breeding mosquito-eating minnows, as well as swamp draining, and road paving to prevent mosquitoes from thriving in stagnant water sources (Black, 1986; Packard, 2007). These efforts targeted the malaria parasite directly from the source, before the human host was infected. In addition, workers were given antimalarial medications to eliminate rapid transmission of the malaria parasite. According to Black (1986) these efforts later proved successful in North and South America as well as in Europe.

In the 1920s there was a profound emphasis placed on the relationship between malaria and socioeconomic conditions. Eradication strategies garnered multifaceted approaches to prevention and treatment which included fostering improvements in living

conditions and sanitation, political reforms, ecological adaptations, as well as vector control¹² (Black, 1986; Packard, 2007). Researchers and policy workers recognized malaria as a social disease, increasing in severity when living conditions were impoverished. However, by the 1930s, in response to groundbreaking biological and medical discoveries, eradication strategies moved towards the use of pesticides and antimalarial drugs, without a broad concern for the social conditions in infected regions (Black, 1986; Packard, 2007).

In the 1940s, profound success in malaria eradication was observed in Italy using widespread chemical spraying (Black, 1986) and by the 1950s the world seemed intent on using chemicals such as dichlorodiphenyltrichloroethane (DDT)¹³ to end the rising malaria epidemic. We now know these successes were short lived, but nevertheless, they provided hope of a world free from malaria. In 1955, following the successful eradication of malaria from Brazil from 1939 to 1941, Dr. Fred Soper of the Rockefeller Foundation partnered with UNICEF to bring about the world's largest eradication campaign in history (Black, 1986; Packard, 2007). Before long, the WHO and the International Cooperative Initiative¹⁴ was onboard with this worldwide venture (Black, 1986). Universal termination of malaria was now the possibility that the world was cooperatively seeking. However, the universality of the venture was essential; malaria is a highly communicable disease and all regions had to participate in eradication strategies if there was to be global success (Black, 1986; Packard 2007).

The 1950s and 1960s saw three main stages of malaria eradication tactics, the attack phase¹⁵, the consolidation phase¹⁶, and the maintenance phase¹⁷ (Black, 1986;

¹² Vector control simply refers to targeting malaria prevention within the mosquito, before parasitic transmission occurs.

¹³ DDT was used globally as a chemical prevention measure that crippled the anopheles mosquito, preventing it from infecting humans.

¹⁴ The ICA was the predecessor to today's USAID (Black, 1986).

¹⁵ The attack phase was intended to be a three-year project that removed the malaria parasite from the blood streams of previously infected individuals (Black, 1986).

¹⁶ This six-year phase was meant to treat all new cases of malaria infection and monitor previously infected individuals.

¹⁷ The final stage of malaria eradication was a maintenance stage in which eradication methods were monitored to ensure the sustainability of previous malaria control efforts (Black, 1986).

Packard, 2007). The world waited with bated breath as monumental expectations of success were forever increasing. Efforts began to look promising in Mexico after just 18 months (Black, 1986), and successes were loudly praised; for the first time, governments, foreign aid groups, and non-governmental organizations (NGOs) alike were addressing a worldwide health intervention. By 1970, 24 countries achieved malaria eradication through the global attack on the disease (Packard, 2007)¹⁸. However, as was the case in Italy in the early 1900s, successes appeared short-lived as the attack phase was still in ongoing six years after the project began, and funding became more elusive (Black, 1986). According to Black (1986) by 1959, UNICEF had diversified its aid recipients and reduced their investment in the eradication campaign from nine million USD to only three million USD over four years. By 1964 eradication was no longer the goal and strategies shifted focus to preventative and control programs.

By 1970, many of the countries that had previously been successful in eradicating the disease were once again submerged in the malaria burden (Black, 1986). By this time, the harmful and toxic effects of DDT were being highly publicized and once again, tactics changed to favour preventative and treatment medications, which targeted the malaria parasite from within the human host, post infection. As Black (1986) suggests, the worldwide approach to malaria had come full circle; from targeting mosquito breeding grounds before transmission was understood, to traditional cures of indigenous populations, to chemical spraying to control transmission through mosquitoes, then back to controlling malaria with the use of antimalarial drugs.

As Tanner and Savigry (2008) suggest, efforts to eliminate the disease following the abandonment of the unified stance have, for the most part, focused on the research and development of new treatment medications and vaccines. A new found focus on science has emerged, and the importance of treating malaria differently depending on the parasitic specie has become apparent. In addition, the introduction of ITNs has flourished

¹⁸ The following countries achieved malaria eradication by 1970: Australia, Brunei, Bulgaria, Cuba, Dominica, Grenada, Hungary, Italy, Jamaica, Mauritius, Netherlands, Poland, Portugal, Puerto Rico, Reunion, Romania, Saint Lucia, Singapore, Spain, Taiwan, Trinidad Tobago, United States, Virgin Islands, and Yugoslavia.

in the developing world with many international aid agencies, celebrities, governments, and NGOs advocating their use in the global fight against malaria. Correspondingly, development economists have become progressively interested in the costs and benefits associated with malaria eradication techniques as well as quantifying the indirect impacts of malaria on developing economies. Since the 1970s a substantial body of research has investigated consequences of the disease on variables such as human capital, direct foreign investment, education, poverty, infrastructure, GDP, infant mortality, and labour-saving technologies. Perspectives and attitudes about how to effectively abolish malaria have fluctuated throughout its history. However, what has not changed is the global conviction that malaria is a curable disease that continues to kill millions of people each year; a disease which is far from being extinguished.

In the 1990s a renewed sense of commitment to global malaria eradication surfaced. After the realization that several countries (including the United States, Italy, Brazil, Venezuela, Maldives and Tunisia) had successfully eradicated the disease, the world was once again anxious to continue the pursuit of global elimination. In 1998, WHO launched the Roll Back Malaria Initiative (RBM) with the goal of essentially eliminating the epidemic from the developing world. The RBM Global Malaria Action Plan stipulates that elimination requires “reducing to zero the incidence of locally acquired malaria infection in a specific geographical area as a result of deliberate efforts with continued measure in place to prevent re-establishment of transmission” (RBM, 2011). Under this program, countries with no malaria infections over a three-year period can apply to become certified as “malaria free”. Importantly, the initiative emphasizes the social implications associated with malaria and is striving to present the necessary funding, knowledge, and technology required to beat the disease burden to countries in need of assistance (Packard, 2007). This initiative relies heavily on the interactions of academia, development organizations, governments and NGOs as a multidisciplinary approach to eradication. RBM hopes to have eight countries certified as malaria-free by 2015. Whether or not this goal will become reality is yet to be seen, however, there is still much we can learn from past attempts at malaria eradication that will aid us in collaboratively achieving this goal in the foreseeable future.

By 2005 successful eradication was seen in Morocco and Syria, and hopes of recreating this result in additional African countries manifested. Unlike previous global eradication campaigns, RBM made SSA its main priority, recognizing it as the region hardest hit by the epidemic. In the same year, President George W. Bush launched the *President's Malaria Initiative*, pledging more than 1.2 billion USD to combat malaria in several African nations. Awareness and ambition regarding the likelihood of malaria eradication grew steadily and countries pledged their renewed commitment to the elimination of the disease once and for all. In 2007, Rick Mercer, in affiliation with UNICEF, began the *Spread the Net* campaign targeting malaria eradication in Liberia and Rwanda (Spread the Net, 2011). This program was aimed at fundraising money to purchase ITNs in more than 250 Canadian schools, and successfully raised more than \$300,000 in its first challenge. Dalhousie University won this campaign, raising over \$19,000 in 2007 alone (Spread the Net, 2011). In 2009, the Spread the Net campaign more than doubled its funds raised, and the initiative continues to be promoted throughout Canadian universities. In total, more than 501,000 bed nets have been provided to accepting regions in SSA through this program (Spread the Net, 2011).

2007 marked the Gates Foundation's monumental commitment to malaria eradication. That organization continues to work tirelessly to develop an effective and affordable malaria vaccine pending a goal of completion by 2025. In the meantime, they are investing in multiple control techniques to negate the adverse outcomes associated with the disease. In 2007 the organization brought the world's leading malaria experts from various fields together in Seattle, Washington, to discuss the best plan-of-action to once and for all conquer the persistent disease; a much anticipated testament to the world that this eradication campaign would be multi-dimensional and all-encompassing (Roberts and Enserink, 2007). Learning from previous failures, activists ensured that the same "malaria hysteria" that originated in the 1960s did not lead to temporary and ill-considered consequences.

After decades of attempting to eradicate this mosquito-borne disease, how have our efforts not succeeded in a more universal fashion? Perhaps the answer to this question lies in the forgotten social and economic factors associated with the disease, as well as

the lack of previous attention to malaria megacentres such as SSA. Although the above discussion is by no means a comprehensive review of the global stance against malaria that has perpetuated since the 1990's, it does allude to the collective action that continues to occur in response to the epidemic. It is comforting to see that the hardships associated with malaria have been recognized and that countries are making a unified effort to combat the disease. However, we must ensure that this unification is not in vain; we must challenge historical thinking and ensure that we provide effective and sustainable relief to the populations most inhibited by the epidemic.

The tribulations of malaria eradication continue today. Should we target the epidemic from mosquito breeding grounds, or should we devise a preventative vaccine to administer to children? Are ITNs an effective way to approach the disease burden? If so, how do we adequately and sustainably provide these devices to individuals in rural and urban regions of the developing world? How do we ensure that our interventions actually reach the poorest, most vulnerable, and most susceptible populations? The subsequent section of this paper discusses the use of several malaria eradication, prevention and control strategies and suggests, a framework for future campaigns based on historical experience.

4.2 Examining Common Interventions

4.2.1 Insecticide Treated Bed Nets

Throughout the past decade, insecticide-treated nets (ITNs) have become one of the most widespread and revered malaria eradication methods. Figure 11 shows the percentage of people using ITNs in SSA. Through celebrity endorsement, it has become fashionable to support campaigns such as Spread the Net, Nothing But Net, Netting Nations, and Malaria No More, all of which raise money to send ITNs to the Latin American and SSA countries most vulnerable to the epidemic. As a malaria eradication strategy, ITNs are relatively easy to produce, transport, and disperse and these elements have contributed to the recent provision of millions of ITNs worldwide.

As with other malaria interventions, ITNs have many costs and benefits that garner consideration when addressing eradication concerns. ITNs constitute a short-term intervention typically lasting only 2-3 years before retreatment is necessary. This can be great for bed net producers, but not for susceptible citizens. This becomes a continuous problem if new nets or treatment stations are not within close proximity to the individuals in need. In addition, ITNs have the benefit of killing anopheles mosquitoes on contact. Nonetheless, if the mosquito does not come in contact with the bed net then it will remain unscathed. As Baume (2007) reports, recipients typically value the ITNs ability to eliminate the pesky mosquito, and therefore often prefer this intervention to the popular indoor residual spray (IRS). From a monetary perspective, the costs associated with ITNs are low, amounting to less than 10 USD apiece. Additionally, when used properly, treated bed nets provide adequate protection by creating a physical barrier between unsuspecting humans and the dreaded anopheles mosquito, herein lays the caveat. Individuals are only protected when they are inside of an ITN used in an appropriate manner. Complete protection would require people to don a personal ITN each day starting at dusk until sunrise the next morning while anopheles mosquitoes are active. I need not emphasize the impracticality of that notion. However, Harris (2010) ironically attests to the absurdity by proposing that, in the developed world, the parallel would be “distributing medical masks all over the US in the winter to save the 36,000 Americans who die every year from the flu” (p. 2). In reality, people do not spend the hours between 6 pm and 7 am solely inside the protection of an ITN, which are not always free from unnoticed rips. Therefore, bed nets should be implemented as part of an eradication campaign, not as the sole strategy.

Unlike other malaria eradication methods, ITNs require virtually no administrative inspections post distribution. These elements make dispersal of bed nets appealing to both local and international agencies targeting the epidemic. In addition, ITNs give individuals a sense of protection; being able to hang a material commodity to safeguard against the disease undoubtedly makes people feel more secure than an intervention that they cannot see or physically touch.

Unfortunately, ITNs are not always used in the intended manner. Too often, bed nets are distributed without concern for accompanying education programs that teach

families how to use the nets effectively. This is of great concern given that sporadic and inconsistent use of the nets proves ineffective in the long run. In addition, malaria nets can be used for a multitude of purposes that serve basic needs including material for traditional dress, curtains, fishing tools, totes, bed sheets, and backpacks. This highlights a shortcoming too often common to international aid - a lack of foresight and insight - emphasizing the importance of context-specific interventions. For instance, human nature requires us to make the most of scarce resources. Finding multiple uses for a new, sizeable, and tightly knit net should be considered inevitable, not unforeseeable. A further issue lies in the difficulties associated with ITNs in small African dwellings. Frequently, a room is only big enough to allow one net and given walls of clay, brick, and mortar, it is often exceedingly challenging to find a way to secure the net into position. ITNs can also be often provided to families without rope or hooks to adhere to the walls or ceilings, and therefore, bed nets are too frequently thrown in a corner or put to use in a more effective manner, providing essentially no protection against the blood-seeking mosquito.

A further thought concerns the production of malaria nets. Following North American and European movements to implement ITN nets in the developing world, there has been a dramatic global increase in the demand for bed nets, and entire factories are dedicated to their production. One such factory in Rwanda produces over 12 million ITNs annually (East Africa Business Week). This could offer increased employment and revenue for the same regions that are benefiting from the use of the protective commodities. Additional research should be carried out to investigate where most ITN production is taking place. If the majority of worldwide ITN production takes place in the developed world, we must at least question our incentives in the process. Are we providing ITNs because they are the most cost-effective, accessible, and sustainable strategy? Or, do we encourage them because it is the easiest intervention for us to distribute, and because we are economically gaining from the production of the intervention on our own soil? Malaria nets are convenient in that they allow donating bodies to feel they are making a tangible and materialistic difference in the lives of others. For instance, purchasing one ITN for an individual in the developing world seems more likely to encourage donations than contributing broadly to research and development.

A number of recent studies have reviewed the effectiveness of dispensing ITNs in the developing world. For instance, Baume (2007) conducts a study in Ethiopia to determine bed net utility when the intervention is provided free of cost. She finds that 91 percent of households own at least one ITN. Figure 12 and 13 show the percentage of SSA households owning more than one ITN and sleeping under an ITN, respectively. At first, this seems a rather impressive statistic given that many regions of SSA did not have access to insecticide-treated bed nets prior to the turn of the decade. However, I believe this statistic is in essence, quite misleading. In SSA, small houses typically encompass extended families and can support upwards of 10 or 15 people. In this situation, of what benefit is it to know that the household possesses one bed net? Unfortunately, many authors may take these statistics as “irrefutable” evidence that malaria nets are providing protection to thousands of households in SSA. Similarly, studies concerning malaria prevention include statistics about the number of children under five and the number of pregnant women that are protected by bed nets. For reference, similar statistics are shown in figure 14 and 15. In a region where numerous children may be sleeping on the floor and large families are quite common, this statistic again skews the reliability of how consistently bed nets are being used. Furthermore, studies claiming fifty percent of children are protected by ITNs are not concerned with children over the age of five. In fact, in the Demographic and Health Surveys databank, children older than five are not even tested for malaria, making it difficult to estimate long-term benefits of ITN coverage.

Baume (2007) cites the two most common reasons for not owning ITNs as the belief that malaria does not constitute a significant threat to African families, and a lack of appropriate advertisement regarding the distribution of bed nets. Baume (2007) also reports that the majority of households surveyed were not certain if bed nets could be washed without removing all of the insecticide. This leads to bed nets being excessively dirty, or being discarded too frequently. These findings highlight two problems with foreign aid in response to the national epidemic. First, educational awareness programs focusing on the destructive consequences of malaria should be offered when distributing ITNs to encourage households to use their bed net(s) for the intended use. Second, one-time interventions will simply not cut it. If we are committed to offering assistance we

must ensure that we are reaching as much of the target population as possible.

Baume (2007) also found that many freely distributed ITNs were sold to local merchants who then redistribute the nets at an increased cost. The author reports that “in an effort to avoid the free nets being resold, some [aid distributors] opened the package before giving it to families. However, these opened packages were also found in the market”. One might anticipate that anyone privy to culture in a developing region would understand how markets work. This is a somewhat comical example of how western attitudes are often inappropriately attributed to foreign cultures. Similarly, the distribution of ITNs, through cost-sharing initiatives or free dispersal, has received significant attention from academics (Cohen and Dupas, 2010; Kirigia, 1997). Some believe that cost sharing increases effective ITN use, while others argue ITN protection will be foregone if citizens are charged to avail of the commodities. Cohen and Dupas (2010) find that pregnant women in Kenya who receive freely dispersed ITNs are just as likely to use them effectively as women who paid for the protective device. However, the authors report that charging subsidized prices for ITNs stifles demand by approximately 60 percent (Cohen and Dupas, 2010). Therefore, it is important to consider the way in which ITNs are provided or sold to individuals in low-income countries.

In conclusion, I suggest that many initiatives targeting the malaria epidemic bring about some degree of positive change, if only in the awareness they beget. Due to its communicable nature, preventing malaria in even one individual will ultimately decrease the chance of further parasitic transmission. In this way, all individuals will indirectly benefit from an increase in malaria eradication, even if they do not personally have access to the intervention. What is the “net” effect? ITNs provide a sense of security and are easy to distribute, however, bed nets, whether treated or not, will not end this epidemic in isolation. We now know the most effective way (better yet, the only way) to eradicate the disease is a comprehensive approach encompassing environmental workers, psychologists, scientists, aid workers, teachers, and factory workers in collective cohesion. I do not discredit the progress made in this area, I simply beg development agencies, governments, and NGOs to take a closer, more altruistic look at their actions and to use caution when interpreting the statistics associated with bed nets. For instance,

the Spread the Net Campaign website claims over 500,000 lives have been saved due to the distribution of bed nets. This may very well be true, but it also may be skewing our belief of how effective this intervention truly is.

If I were in SSA, would I sleep under a bed net? The simple answer is of course I would (and I have) even if only for my own sense of security while vulnerably sleeping. I applaud those distributing this sense of security to developing populations. However, I caution the promotion of this action as the sole strategy to end the global fight against malaria. Research since the 1970s has shown us that as long as the anopheles mosquito continues to breed, people will continue to endure the devastating complications of malaria. Similarly, elimination of the parasite will not occur without universal access to treatment and preventive measures. IRS, although costly and relatively short-lived, is required to protect individuals within their own homes, and widespread chemical spraying should be implemented to target the mosquito from the source, prior to its transmission of the parasite to humans. In addition, widespread education and awareness programs are essential to any eradication pursuit, and they should not be ignored.

4.2.2 Vector Control, Indoor Residual Spray, and DDT

In addition to ITNs, there are several preventative malaria strategies that target the inhibition of human infection through combating the anopheles mosquito. Swamp draining, and the breeding of mosquito-eating minnows, as described previously were two eradication methods historically employed to target mosquitoes directly from the breeding source. Intuitively, these strategies were aimed at preventing the reproduction of the malaria parasite within the anopheles mosquito, thus avoiding human infection. As Packard (2007) reports, larvicides were also developed as a form of vector control. These methods of prevention were beneficial in their relative simplicity; they did not require immense collaboration between local, national, and international entities. Instead, small groups of workers could finalize the initiative in a timely matter through ecological adaptation (Packard, 2007). These environmental changes theoretically had the potential to be long lasting, and therefore posed a reasonable possibility of achieving malaria eradication. In addition, these methodologies were partially responsible for the successful eradication in Panama during the construction of the Panama Canal. These methods were

locally derived and did not require intricate research and development or monumental international funding. Overall, vector control was relatively cheap to implement. Today, however, environmental conservation representatives may meet these methods with opposition.

One disadvantage of these forms of vector control was the illusive emphasis placed on educational awareness and public behavioural changes. Small groups of workers eliminating mosquito breeding grounds required little public education or personal adaptation, which led to negligible changes in socioeconomic functioning. Secondly, swamp-draining and puddle-filling was often dangerous work with labourers exposed to significant health risks, including the acquisition of malaria. These consequences are rarely quantified in economic analysis. These forms of vector control were also impractical to employ in pursuit of global eradication given the vast number of potential breeding grounds. In addition, the initial costs associated with such preventative initiatives were sizeable, given that environmental engineering required precise knowledge of mosquito breeding habits, and local terrain. Similarly, significant labour supply was required once aggregated at a national level.

In the mid 1940s, DDT was invented as a source of vector control and its mass killing potential was unleashed (Packard, 2007). Before long, it was the method of choice for malaria eradication, and it was a major factor in the successful eradication of malaria from the United States, Latin America, China, and Europe in the late 1960s (Packard, 2007). DDT was relatively inexpensive and effective. Worldwide eradication campaigns invested millions in its potential. DDT was the secret weapon of the 1960 worldwide eradication push. It was generally believed that this new technology would allow infectious disease to be eliminated rapidly and sustained indefinitely. However, resistance to DDT appeared shortly after initial application and success required consistent and repeated coverage, highlighting the unforeseen consequences of a single approach to eradication. In addition, DDT was not only a super threat to the perfidious mosquito, it also harmed farm animals, pets, and posed significant health risks to humans.

Today, IRS is one of the most common methods of vector control requiring pesticides to be sprayed on the walls of houses in areas of high malaria transmission.

Figure 16 shows the percentage of IRS coverage in SSA countries. According to the WHO (2012) IRS should be the main focus of malaria reduction strategies at the municipal level, as it is the only form of vector control that has the individual ability to reduce malaria prevalence in highly endemic regions to negligible amounts. However, IRS is at optimal efficiency only when 80 percent of homes are treated twice annually (WHO, 2011). Given what we know about previous eradication attempts, this may not be feasible in SSA where malaria is only one deadly disease burden amongst a barrage of poverty-related illnesses and destitution. Although IRS is relatively effective, it requires abundant labour supply and is only protective if mosquitoes land directly on house walls prior to biting humans. Unlike DDT, IRS does not prevent mosquitoes from breeding, nor does it necessarily require behavioural adaptations to help eliminate the disease burden. In the absence of these elements, malaria eradication may be short lived at best. IRS, in addition to individual ITN usage may be required to protect individuals within their own homes, in conjunction with a widespread chemical initiative to target the breeding source of the mosquitoes prior to transmission. As I have maintained throughout this paper, the best tactic for malaria eradication is a comprehensive and varied approach.

4.2.3 Preventative Medications

As shown in Figure 17, antimalarial medications constitute the largest malaria control intervention. Figure 18 shows the percentage of antimalarial coverage in SSA. Current prevention medications typically include traveller's chemoprophylactic¹⁹ pills, such as chloroquine, doxycycline, mefloquine, and primaquine (RBM, 2011) as well as sulfadoxine-pyrimethamine intermittent preventative treatment (IPT)²⁰ administered to pregnant women, young children, and infants (WHO, 2011). Each of these aforementioned drugs is applicable to a particular subset of patients dependent on the species of the parasite, acquired drug resistance, the health status of the patient, geographical location, and pregnancy considerations (CDC, 2011). However, no preventative medication is 100 percent effective (CDC, 2011). In addition, although

¹⁹ Chemoprophylaxis are simply drugs used to prevent disease burdens.

²⁰ IPT refers to treatments that combine the elimination of existing malaria parasites with the prevention of further parasitic transmission.

administration of these pills is simple (most preventative medications are taken orally) travellers pills can result in severe side effects including night terrors, nausea, and suicidal tendencies, deterring many travellers from accepting this medication.

Unfortunately, antimalarial drug resistance is a prominent problem that hinders effective prevention programs, especially in SSA. Drug resistance occurs when mutations block drug access to the Plasmodium, allowing the malaria parasite to continue rapid asexual reproduction (RBM, 2011). When the Plasmodium resists antimalarial treatment, morbidity and mortality rates increase and human transmission is amplified. East Africa has recently experienced a resistance to chloroquine. This resistance is believed to have originated in Tanzania in 1979 and has progressed rapidly ever since (RBM, 2011). This antimalarial resistance partially accounts for recent increases in morbidity associated with malaria in SSA.

To date, there is no satisfactory malaria vaccine to fully prevent infection. The most sophisticated vaccine is RTS,S (or Mosquirix), which primarily targets Plasmodium Falciparum infections. According to the WHO (2012) this vaccine is currently undergoing several stages of clinical trials in multiple African countries, and the success or failure of the vaccine should be reported late in 2014, with final decisions regarding its widespread use to be made in 2015. Impressively, RTS,S clinical trials are being undertaken in several regions severely impacted by malaria. Tanzania was ranked by RBM (2011) as the fourth highest in terms of the number of malaria cases treated each year, and RTS,S clinical trials are currently ongoing in the Tanzanian region of Bagamoyo (Regules, Cummings, & Ockenhouse, 2011). The potential success of the RTS,S vaccine is undoubtedly exciting, however, the feasibility of providing this vaccine to those in need, will remain to be seen. As with any medical intervention, the first step is developing a feasible and effective medication, and the second is brainstorming how to make the discovery affordable and accessible to the individuals it is intended to help.

Although a fully preventative vaccine is years from completion, partial immunity against the chronic Plasmodium parasite does often occur in some regions of SSA, the Middle East, and India (Gallup and Sachs, 2001). The mechanisms behind this acquired immunity are poorly understood, but the timely progression seems readily apparent; for

many individuals acquiring immunity against malaria's deadliest side effects in early adulthood, reduces the mortality and morbidity associated with the parasite in chronically infected regions (Holding and Snow, 2001). Packard (2007) suggests that after millions of years, many Africans have acquired a genetic adaptation that allows immunity from the parasitic infection. These adaptations include Duffy negative red blood cells, which offer immunity to Plasmodium Vivax, and hemoglobin S, which provides resistance to Plasmodium Falciparum (Packard, 2007). However, this immunity is not free from heightened vulnerability. Through previous failures at malaria eradication, the unsuspecting disappearance of this acquired immunity has become horrifically apparent. According to Packard (2007) immunity relies on repeated exposure to the malaria parasite. When temporary eradication disrupts this cycle, those previously immune once again suffered extreme susceptibility. Given this view, worldwide eradication attempts actually left some regions worse off than prior to the intervention. This finding highlights the complexity associated with eliminating the malaria parasite and the ramifications of unknown consequences, despite the best intentions.

There are several limiting factors to consider with regards to preventative malaria medications. First, malaria preventative medications are not recommended for extended, long-term usage; typically, travel clinics only prescribe a three-month supply for extended travel. In addition, the distributional issues associated with medication provision cannot be ignored. Expiration is a time-restricted component that cannot be overlooked. If medications are out-dated they must not be consumed and must be disposed of efficiently. Secondly, transportation of these medications proves to be excessively difficult; medications often require storage at specific room temperatures, and prudently delicate shipment. In addition, donating organizations need to be conscious of the language requirements of the receiving destination. In my own travels, I witnessed the heartbreak and disappointment that can result when a long-awaited shipment of medications arrives with labels printed in a language completely foreign to the receiving population. It is of no benefit to provide "assistance" that is ill-considered and inadaptable. Lastly, the administration of many preventative medications requires access to a health facility, which as we know, is not always possible in many rural regions of

SSA. Each of these concerns once again highlights the importance of a multidimensional approach to malaria.

4.2.4 Treatment Medications

There are several divergent forms of malaria treatment medications. Some, like chloroquine and quinine, are primarily aimed at alleviating symptoms, others seek to prevent reinfection or to prevent future transmission (Packard, 2007). Like preventative medications, the application of treatment measures depends on the individual, the parasitic specie, and the acquired plasmodium resistance in the region. Most cases are treated orally, however, Plasmodium Falciparum requires intravenous intervention (RBM, 2011). Unfortunately, the same pitfalls of access, affordability, and feasibility apply to treatment medications as well.

According to the WHO (2012), artemisinin-combination therapy (ACT) is the most effective treatment for severe cases of malaria. This treatment uniquely combines artemisinin with other malaria-reducing drugs in an effort to reduce the frequency of parasitic resistance to the medication. Drug resistance has been, and continues to be, a predominant problem with malaria reduction strategies. In the 1970s parasite resistance became evident with both chloroquine and sulfadoxine-pyrimethamine, which significantly contributed to the halting success of worldwide malaria reduction (Black 1986; Packard, 2007; WHO, 2012). Unfortunately, in 2009 artemisinin-resistant parasites also became evident throughout several regions of South East Asia (WHO, 2012). Drug development and resistance will continue to coexist in the future; however, strategies such as ACT aid in preventing this relationship from backtracking realized progress in malaria reduction.

In efforts to avoid parasite resistance to ACT, WHO recommends that malaria only be treated following a parasite-based diagnostic test such as a blood smear, or rapid diagnostic test²¹ (RDT). On the positive side, RDTs can be completed in less than 15

²¹ In most malaria studies, RPT typically involves the pricking of a patient's finger or earlobe before diagnostics are determined at the associated laboratory through microscopic examination

minutes, and are considered to be extremely accurate. However, these tests also require more advanced health care infrastructure and medical professionals trained on microscopic examination; and RDT can cost patients more than a simple visit to a local clinic. It is important to receive accurate diagnosis before treatment medications are distributed, however, in many parts of the world hard-hit by malaria, this may not always be feasible. If RDTs can be established, then it should undoubtedly be used to identify the malaria parasite, however, as is evident in Figure 19, the percentage of people suspected to suffer from malaria far exceeds the number of confirmed cases. Therefore, it should be stipulated that without RDT, treatment could be provided. Regardless of the treatment medication used, early diagnosis is the crucial ingredient in avoiding severe morbidity and mortality. As was discussed in Chapter 2, malaria symptoms are often hard to differentiate from flu manifestations, appearing rapidly and without warning. However, it is imperative that we improve access to health care services, reduce travel time to local health facilities, and preach the importance of early diagnosis in fighting malaria infection. In addition to the above problems associated with treatment medications, compliance is a daunting issue in much of the developing world. Individuals often feel better before the cessation of their intended drug-cycle, and therefore stop taking their prescribed medications. This can have dire consequences on limiting malaria transmission and can significantly increase morbidity. Similarly, in many low-income regions, shortening the duration of medicinal treatments may be essential in affording future treatments. Herein lies the importance of making malaria treatment accessible and affordable; if not for reductions in inequality, then for the possibility of global malaria eradication.

4.2.5 Education and Awareness Campaigns

It is intuitive that increased understanding and awareness of malaria will ultimately lead to more efficient and successful prevention, treatment, and control efforts. At the community level, government officials, health care workers, and educational professionals can collaborate to offer informal awareness seminars regarding the

(Moody, 2002). Nonetheless, methods do vary dramatically, and can be further understood in Moody's (2002) review of RPT protocol.

prevention, epidemiology, and treatment of the malaria epidemic. Simultaneously, international donors and aid agencies providing forms of vector control need to provide adequate training regarding these interventions, if there is any significant chance of ending the war against malaria. In addition, citizens need to be aware of how best to implement and adopt new prevention strategies. No longer can ITNs be dispersed without behavioural adaptation, and no longer can malaria treatments be conserved for future treatment based on a lack of understanding. These concepts are not ground-breaking, however, they can be forgotten in the midst of anxiously deploying preventative measures to needy populations.

As was emphasized previously, malaria limits educational attainment, but also can be limited through increases in education and awareness. Perhaps one of the best multidimensional approaches to the epidemic involves health subsidies offered in reward for school attendance. Although not explicitly related to this paper, health subsidies could help mitigate the hampering effects of malaria illness, while also improving schooling outcomes. In addition, commitments to educational pursuits should not be limited to increasing initiatives in the developing world. It is important that aid agencies, governments, policy makers, and donors in the developed world, continue to invest in malaria research and to make a sizeable effort to gain a better understanding of the regions they are trying to help. Throughout my own travels, I have encountered several issues with ITNs that could have been more accurately predicted had the donors adopted a better understanding of the lives of individuals residing within malaria-stricken regions²². Today we have more textbook knowledge of the malaria epidemic than ever before. Let's couple this long-sought after and impressive achievement with the practical, hands-on intuition needed to make malaria history.

4.3 Can the Eradication Dream Become a Reality?

²² While in Tanzania, I saw ITNs used as fishing nets, tablecloths, wardrobe accessories, and as carriers for wood and food. Children played games with the nets and used them as blankets. These nets certainly satisfied an unmet demand, but they provided no protection against the anopheles mosquito.

In a comprehensive valuation of several of the most prominent malaria interventions, highlighted in the previous chapter, Goodman, Coleman, and Mills (1999) discuss which methods are the most cost-effective to adopt using cost per DALY averted in SSA, and question whether malaria eradication is in fact within the realm of future possibilities. As discussed above, ITNs, IRS, and preventative chemoprophylaxis such as chloroquine are often employed to prevent childhood infections. Goodman et al. (1999) find that the cost-effectiveness of treating ITNs is between \$4-10 USD per DALY averted, while the cost-effectiveness of treating old ITNs is between \$19-85 USD. IRS cost-effectiveness was deemed within the range of \$32-58 per DALY averted, and chemoprophylaxis were measured at \$3-12 (Goodman, Coleman, and Mills, 1999). The authors also investigated the cost-effectiveness of IPT for pregnant women estimating a cost of \$4-2 per DALY prevented. Lastly, the authors estimate \$1-8 required for observation and management (Goodman, Coleman, and Mills, 1999). These results show that there are quantifiably cost-effective approaches to malaria eradication. However, the extent to which these findings are applicable to extremely low-income countries is of great concern. Clearly, one study does not serve as irrefutable evidence, but it does forge a leading path on a daunting road to malaria eradication.

Unfortunately, the multidimensional, and wide-ranging approach that I have continually emphasized in the global fight against malaria may not be affordable to millions living in extreme poverty, especially in SSA. This presents an additional problem in that potential “next steps” in malaria eradication are not entirely feasible given current funding allocations. As Goodman et al. (1999) suggest, substantial achievement in malaria efforts rely on extensive support from international donors, above and beyond that which is currently being provided. In 2010, the WHO estimated the cost of worldwide malaria eradication at 5.126 billion USD, while current annual funding sums only to 1.107 billion USD (WHO, 2011). This requires a substantial increase in global funding to achieve widespread eradication. There are always risks associated with the characteristics of paternalism and dependency when dealing with foreign aid. However, if policy makers, advocates, and academics work together to learn from past failures and garner previously unmet levels of support, there is a great potential that malaria could one day become a disease of the past.

Chapter 5: Discussion

5.1 A Realistic Approach to Malaria Eradication?

Each of the malaria eradication methods previously discussed has some merit. However, even the most successful interventions are increasingly difficult to implement and maintain throughout much of SSA. I argue this is predominantly due to a myopic vision of malaria eradication in which strict time-lines are over emphasized and assured to be achieved. I appreciate the desire for timely feedback, and regular checkpoints in assessing development concerns. However, eliminating a human disease burden from existence is a monumental task that has only been achieved once before²³. Furthermore, success in eradicating malaria would be a feat unmet throughout human history. Therefore, it should be assumed that time-lines will *have* to be extended, funding broadened, and collective action amplified. Although researchers around the globe are continuously finding new ways to qualify and measure the costs associated with malaria and its hopeful eradication, some level of flexibility must be recognized if we are indeed to annihilate this deadly burden. Research regarding the costs of the epidemic is needed for analysis and action; however, we must remember that these are a small component of substantial immeasurable and unobservable consequences of malaria. However, as Lucas (2010) suggests, we can rest assured that the costs associated with eradication are substantially less than the calculated 15-75 USD benefit in GDP per capita which will result from malaria eradication. Moreover, the value of a human life extends far beyond such narrow economic indicators.

Perhaps for the first time we now have the power, knowledge and resources to make malaria a burden of the past. However, before this dream can become a reality our approaches to eradication *must* change. None of these methods can be uniformly implemented to diverse regions. Every malaria-infected region has its own culture, political and belief systems, social norms and development concerns. Although it is

²³ In contrast to several diseases that have been reduced to negligible amounts (or eliminated), Smallpox is the only infectious disease that has ever been eradicated.

imperative to learn from previous mistakes and accomplishments, we need to recognize that no two treatment plans will ever be synonymous.

If the WHO meets its malaria eradication goals it could save millions of African lives annually (WHO, 2010). Unfortunately, there is no precise, universal, and accurate way to quantify the economic value of a human life. Likewise, the cognitive effects, and educational attainment lost due to malaria infection often escape these calculations. However, these meagre statistics are only one dimension of an eradication campaign that includes the altruistic incentive we have as global citizens to stop millions of deaths worldwide through education, knowledge, collective action and international support.

It is essential to abandon the tunnel vision that many organizations have become accustomed to. Throughout history eradication initiatives have repeatedly been overly ambitious and optimistic regarding inevitable and timely success. Similar to a child with a new toy, many become desperate to find the next ground-breaking intervention that will reduce malaria to a distant nightmare. I argue that *no* single method will present these intangible results. As long as poverty, mosquitoes and their breeding grounds exist, malaria will continue to run rampant. Believing that one method can address all of these concerns is extremely dangerous, especially if new found excitement and assurance of continued success leads to decreased investments in international support and research funding. Going forward, we must not ease off our support just as success becomes apparent. This is the time in which the most persistent commitment is necessary. The 1960 eradication attempt was doomed by its extreme reliance on one intervention, DDT. Let us ensure that our most recent prominent emphasis on ITNs does not once again place us on the path of disappointment born from ignorance and complacency.

5.2 Policy Implications and Next Steps

As should be evident, no single malaria eradication strategy will lead to universal eradication in isolation. A strict emphasis on education programs will not reduce severe malaria side effects, facilitate eradication of the malaria parasite in mosquitoes, nor will it necessarily lead to decreased transmission. Similarly, vector control will not lead to

eradication without an understanding of the role of geography, poverty and health in malaria transmission. ITNs, although affordable and easily distributed, cannot prevent malaria transmission in the early evenings, or when used without proper use and knowledge of maintenance techniques.

At the individual level, citizens can adapt their behaviour to avoid increased susceptibility at night, and can take preliminary precautions against malaria infection. This may be as simple as wearing long sleeves and pants after dusk, and can extend to the proper use of ITNs, especially for young children and pregnant women. Households can fill stagnant water sources around their dwellings and avoid swamp areas. If possible (and it often is not) individuals should seek prompt medical attention at the first sign of malaria symptoms, especially in the case of prolonged fever. If resources allow, individuals should also install screens on windows and doors to prevent mosquitoes from entering their homes. Lastly, individuals can ensure that prescribed antimalarial medication is taken with due diligence, and carried out for the duration of the prescription. Increasing access to health care and medications can only be effective if individuals are committed to use medications in the appropriate manner.

At the community level, education and awareness regarding the transmission of malaria should be emphasized. Furthermore, community-wide initiatives to increase IRS and facilitate access to treatment are imperative. Any available control or prevention methods should be employed with a focus on increasing awareness and decreasing vulnerability. Globally, donating entities must strive to continue support, while reducing dependence, and embracing the receiving country's culture and traditions. Our world is not uniform and every technique should be revolutionized in a context-specific manner, in light of previous lessons for eradication challenges.

Massive international assistance is imperative to beating this epidemic. However, it should not take the role of mandating eradication methods in a generalized fashion, irrespective of local concerns. Populations in the developing world must be involved at the individual, regional, and national levels and international policy makers should become better versed in the culture, livelihood, and socioeconomic surroundings of the regions they wish to pull from the wreckage of poverty. After all, what will happen when

eradication goals are delayed and international optimism begins to crumble? Communities should be engaged with initiating education and awareness programs, providing information regarding new methods, and achieving access to local health centers.

Lines of communication must remain open to accurately attest to the most effective approaches to eradication. Who knows better the trials and tribulations associated with the disease than those whose lives are continually threatened? In addition, malaria eradication strategies need to actually reach the poorest, most vulnerable populations. The first step is evidently having ITNs or treatment medication provided in a hyper endemic region, but those provisions also require accessibility by individuals living in that region. Barat et al. (2004) suggest this is increasingly not the case, due to existing inequalities in access to health care services, as well as preventative and treatment medications. Medications can achieve little progress, unless people actually take them in an appropriate manner. Once again, we see the recurring theme that malaria must not be viewed in isolation of socioeconomic conditions.

5.3 Are We Rolling Back Malaria?

The most recent push for global eradication has the benefit of integrating local capacities rather than implementing paternalistic prescriptions and the emphasis on a multifaceted approach seems at least verbally apparent. In contrast to previous initiatives, RBM pledged its focus on relieving the epidemic in the areas most heavily impacted in SSA. RBM also placed significant importance on aiding the most susceptible populations; pregnant women and children, a feat unmet in previous elimination campaigns. In addition to their varied approach, RBM sought to increase awareness and encourage behavioural adaptations. Given these modifications, it is possible that RBM could make a substantial difference in global eradication.

My concern with RBM is the imperative focus placed on ITNs as an individual method of elimination. If we believe that it is possible to have 80 percent of individuals in infected regions using ITNs then by all means, press on. However, if our attempt fails,

let us not focus so carelessly on one intervention as a universal strategy. RBM initiatives have already shown extreme problems associated with ITN distribution and usage in East Africa. Studies have also shown the demand for IPT, so let us use this domestic demand to our advantage and use it to curb malaria transmission. Human cognition is a tremendously important tool to take hold of. Multidisciplinary action is no longer a debate, rather it is a necessity.

RBM has already decreased its allocation of IRS in favour of advocating for ITN usage; a decision that I hope is not a recurring phenomenon. Although RBM's eradication success in Cambodia and Vietnam is undoubtedly an admirable success, few African nations have met their target reduction goals (Packard, 2007). Unfortunately, success is dependent upon international aid and support and in lieu of the 1960s campaign when international donors eventually left the worldwide effort to support other causes, how long do we expect aid agencies to continue focusing their efforts on a "tropical" disease, especially in the face of global recession? So let's recognize these pitfalls now rather than charge full speed ahead into foreseeable failures. In case it was not clear, one method alone will not end the malaria endemic, no matter how much we think we know.

5.4 Malaria Eradication in the MDGs

The sixth United Nation's MDG is to "combat HIV/AIDS, malaria, and other diseases" (UN, 2011). Since the specification of this MDG, global malaria deaths have decreased; several countries have achieved eradication; ITN, IRS, and treatment medication usage has increased; and international support for malaria interventions has been steadily increasing (UN, 2011). Although malaria reduction is directly stated as the sixth MDG, it is not the only goal to which malaria relates. The first goal hopes to "eradicate extreme poverty and hunger" and the second strives to "achieve universal primary education" (UN, 2011). The success of realizing both of these goals would certainly help combat the global malaria burden. As discussed in Chapter 2, poverty, malnutrition, and ill-health increase susceptibility to the acquisition and transmission of malaria, and highlight the importance socioeconomic relations to the global malaria epidemic. Education has the potential to help individuals better protect themselves from

acquiring malaria. In addition, universal education facilitates the adoption of protective behavioural modifications, such as indoor meals after dusk and long-sleeved clothing at night to combat the disease. The fourth MDG expects to “reduce child mortality” and the fifth seeks to “improve maternal health” (UN, 2011). Both of these goals can be, in part, accomplished by efforts to reduce and eradicate malaria. Malaria is the number one cause of death in children under five in SSA and malaria is dramatically hampering maternal health during pregnancy and facilitating harmful intergenerational susceptibilities throughout much of the same region. As always, malaria is a bountiful disease burden, which is closely tied to socioeconomic status, poverty, health, education, and well being.

Whether the MDGs will in fact be reached by 2015 remains to be seen, however, given the failure of previous eradication timelines and the resulting removal of international support and funding, one can only hope that this campaign does not recreate history and suffer the same fate as the global campaign of the 1960s. The world has made its promise to fighting malaria in regions such as SSA, and I hope those promises and commitment remain true. Several authors write about the ignorance of worldwide malaria eradication campaign in the 1960s issuing claims that a singular approach to such a monumental task was sure to fail. Yet, few are bold enough to propose that we may, once again, be heading down a path of paternalism and assurance in our ventures. Today, we know much more about how malaria is transmitted, and about which solutions work best. However, we may not necessarily know “best” what concerns are prominent in a foreign region and how to implement sustainable and meaningful change.

Chapter 6: Conclusion

Fortunately, there is evidence that malaria eradication can become a reality in the foreseeable future. Several European countries including Italy, Greece, Portugal and Spain, have successfully beaten the pandemic (Gallup and Sachs, 2001). According to the Millennium Development Goals (MDG) Report (2011), for the first time in history, Europe reported no cases of plasmodium falciparum in 2009. Similarly, the United States and China have launched extremely successful eradication campaigns. Most recently, the WHO certified the United Arab Emirates (2007), Morocco (2010), Turkmenistan (2010), and Armenia (2011) as malaria free.

Furthermore, in response to RBM and other worldwide eradication efforts, malaria death rates have declined by more than 65 percent in Zambia since the year 2000, exceeding the target reductions postulated by the RBM campaign (WHO, 2009). According to the WHO (2009) between 2006 and 2008, more than 3.5 million ITNs were distributed to infected Zambian regions, IRS was conducted in more than a quarter of Zambian communities, and ACT was highly publicized and endorsed, further attesting to the success that is achievable with multiple reduction strategies operating in unison. Similar to the Zambian success story, 10 other African nations have achieved the goal of attaining a 50 percent reduction in malaria infections including Algeria, Botswana, Cape Verde, Eritrea, Madagascar, Namibia, Rwanda, Sao Tome and Principe, South Africa, and Swaziland (UN, 2011). Globally, malaria death tolls have decreased by more than 25 percent since 2000, with larger reductions seen throughout many African countries (UN, 2011; WHO, 2012).

As was previously iterated, it is impossible to separate the development advancements made by malaria eradication from those resulting from improvements in health care, education, sanitation, equity, and peace. However, I argue that this quantification should not be our primary concern. Of course it is important to recognize initiatives that are deemed successful, however, we must not allow the quest for a number justification to overshadow the beauty in a truly multi-dimensional approach to global eradication.

Malaria is a daunting epidemic that has taken the world by storm. Despite our perpetual efforts, the disease continues to infect millions of individuals worldwide, and malaria parasites continually evolve and resist our persistent eradication pursuit. More than any other infectious disease, malaria has captured the attention of scientists, academics, humanitarian workers, school populations, and individuals, all hoping for a day in which the epidemic is merely a lesson taught in high-school history courses. The most prominent and influential global organizations, including establishments such as UNICEF, the WHO, the World Bank, the IMF, and the Bill and Melinda Gates Foundation, have committed resources to beating the malaria epidemic once and for all, and we are closer to success than ever before.

The “hysteria” associated with malaria’s unforgiving morbidity is only succeeded by the frenzy associated with developing and implementing new, ground-breaking eradication strategies. Both of these emotions can be subsided. Malaria is most often curable with inexpensive medications, meaning millions of lives await saving through increased access to and affordability of these medications. Similarly, we now have enough information and experience in targeting the epidemic to pursue eradication in an informed and educated manner.

No disease epidemic has proved harder to control or eradicate than malaria. It is an extremely sophisticated and adapting disease, which will continue to test our ingenuity, resourcefulness, and stamina for decades to come. However, if we adopt a multi-dimensional, all-encompassing approach to eliminating the deadly epidemic, then eradication could be within our grasp. Past eradication attempts have shown us how devastatingly persistent malaria can be. However, we now have within our grasp a great opportunity to finally eliminate this disease burden, making a sustainable and effective difference in the lives of millions. The question is, will we accept that responsibility whole-heartedly?

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Appendix: Figures

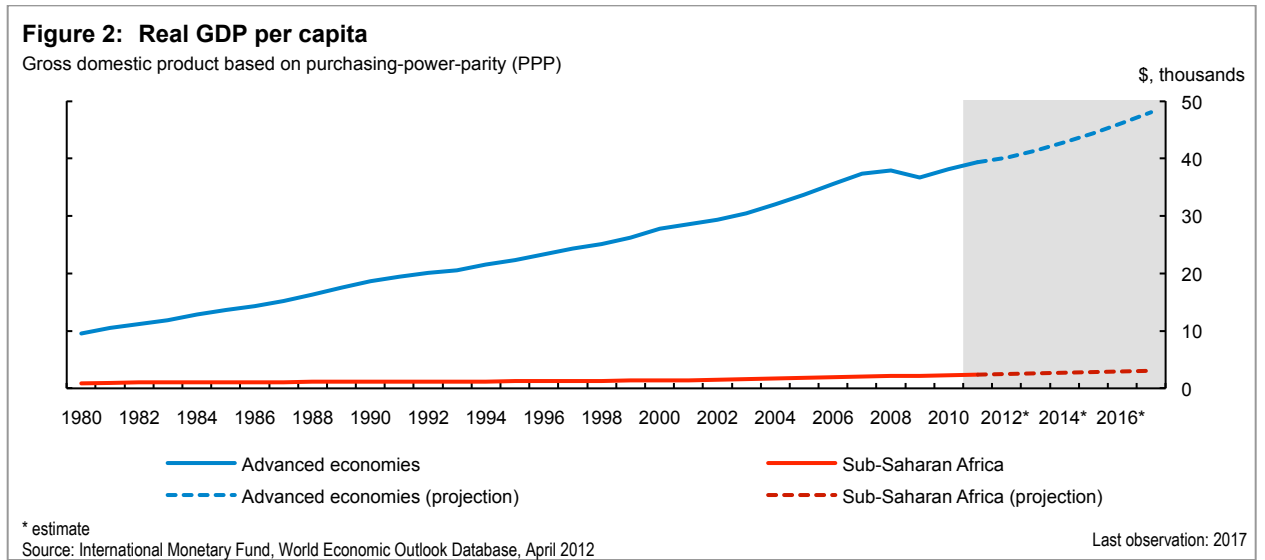
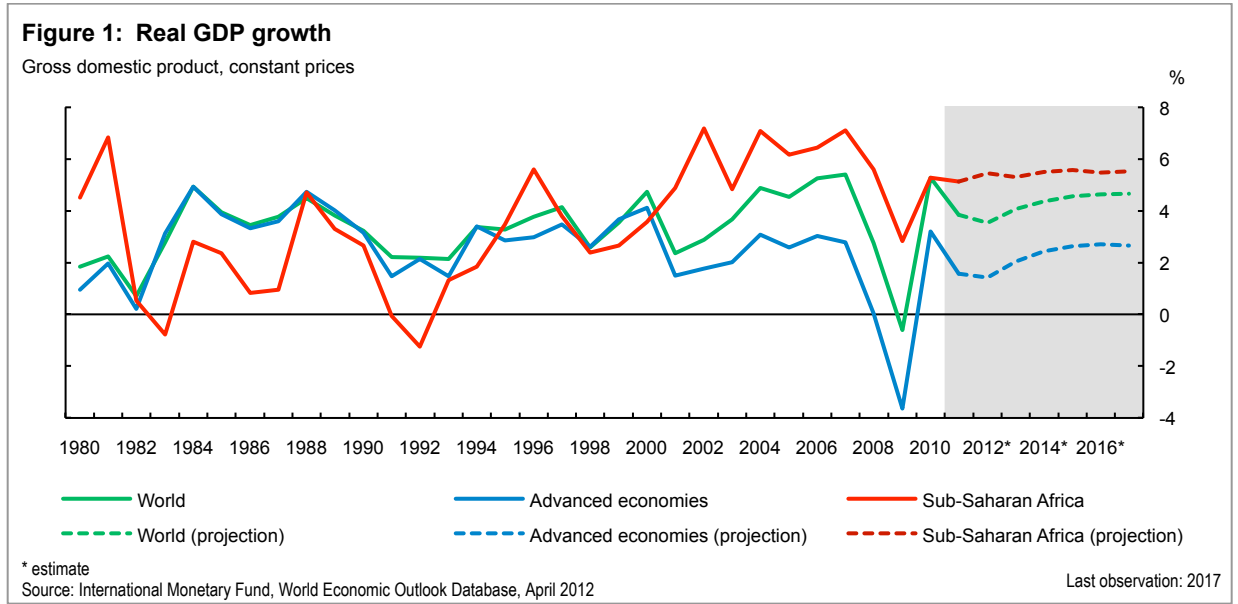
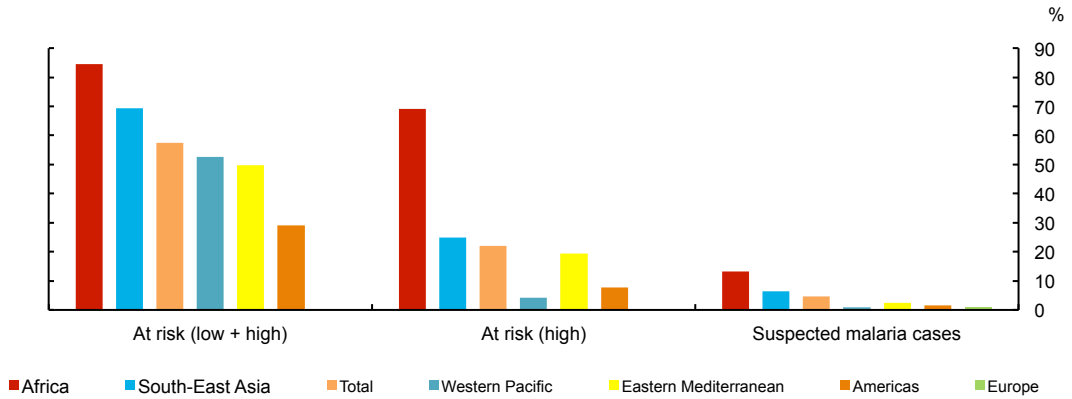


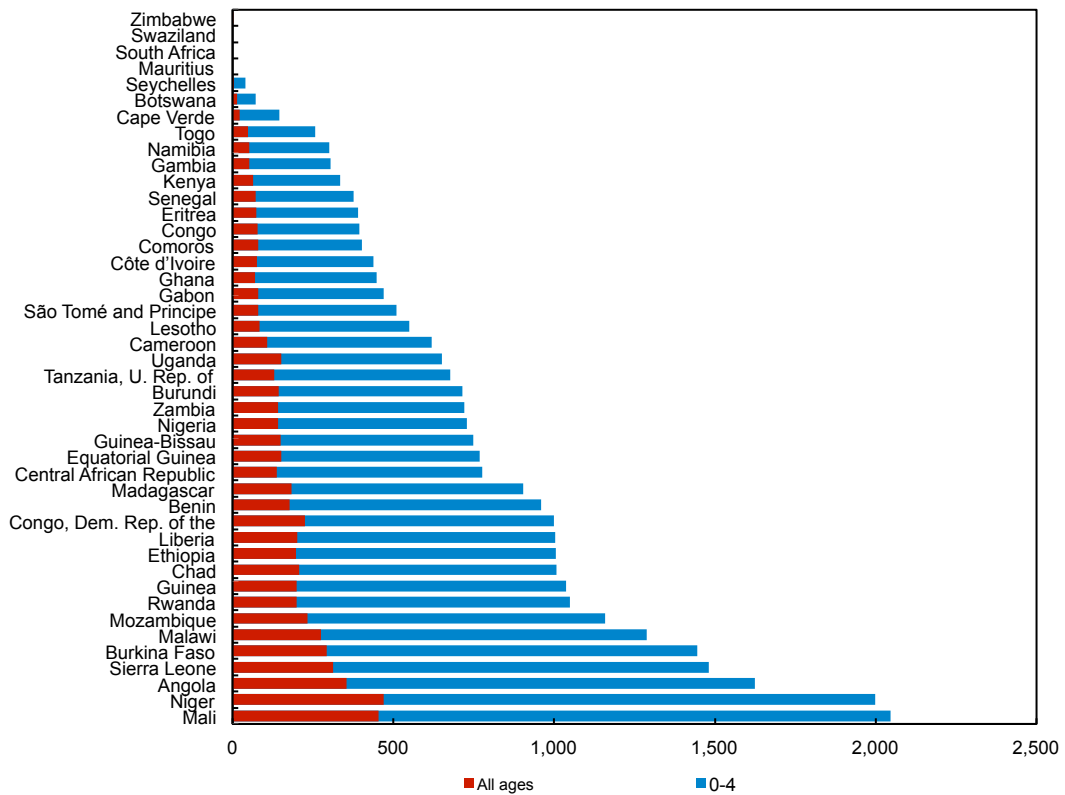
Figure 3: Percentage of populations at risk for contracting malaria



Source: World Health Organization, World Malaria Report (2011)

Last observation: 2010

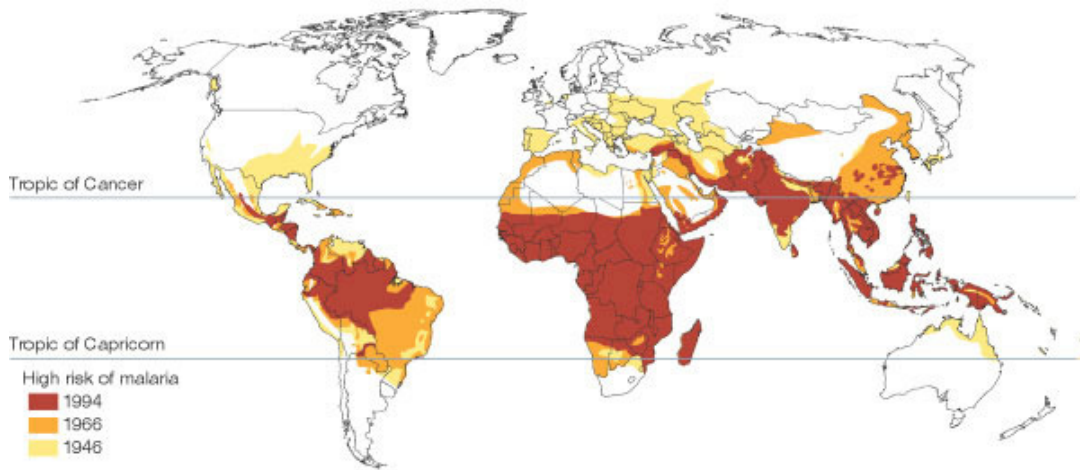
Figure 4: Malaria-related death rates per 100,000 people



Source: United Nations Development Programme, Human Development Report (2003)

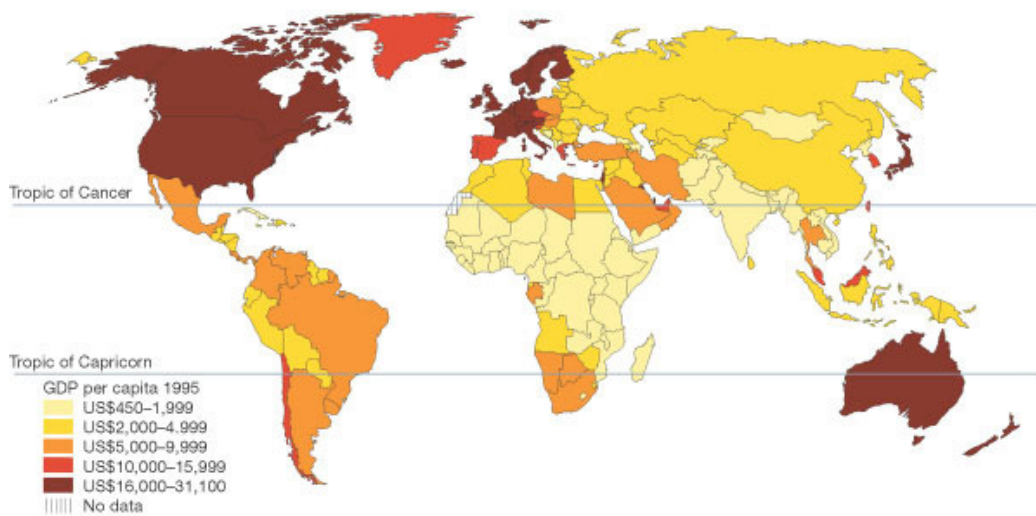
Last observation: 2000

Figure 5: Global Distribution of Malaria



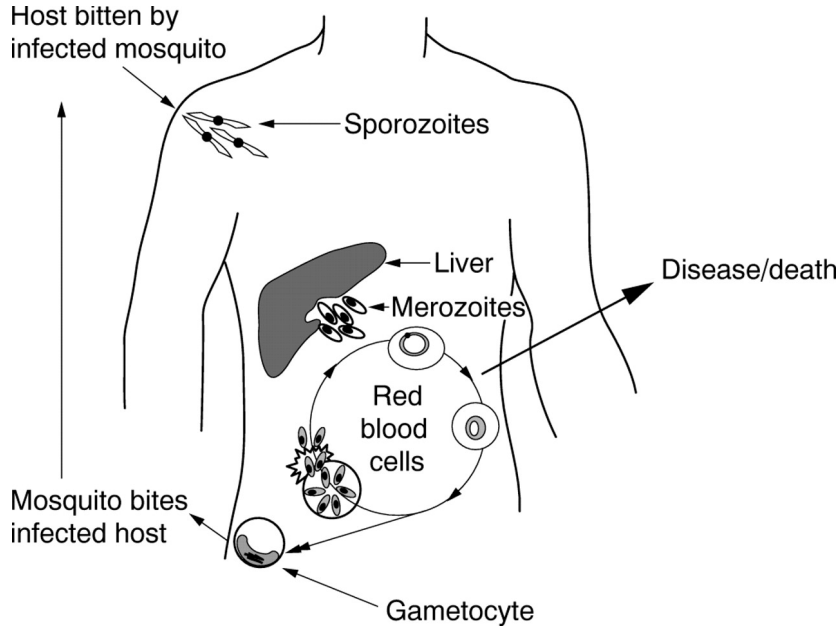
Source: Gallup and Sachs (2001), p. 86.

Figure 6: Global Distribution of GDP per capita in 1995 Dollars



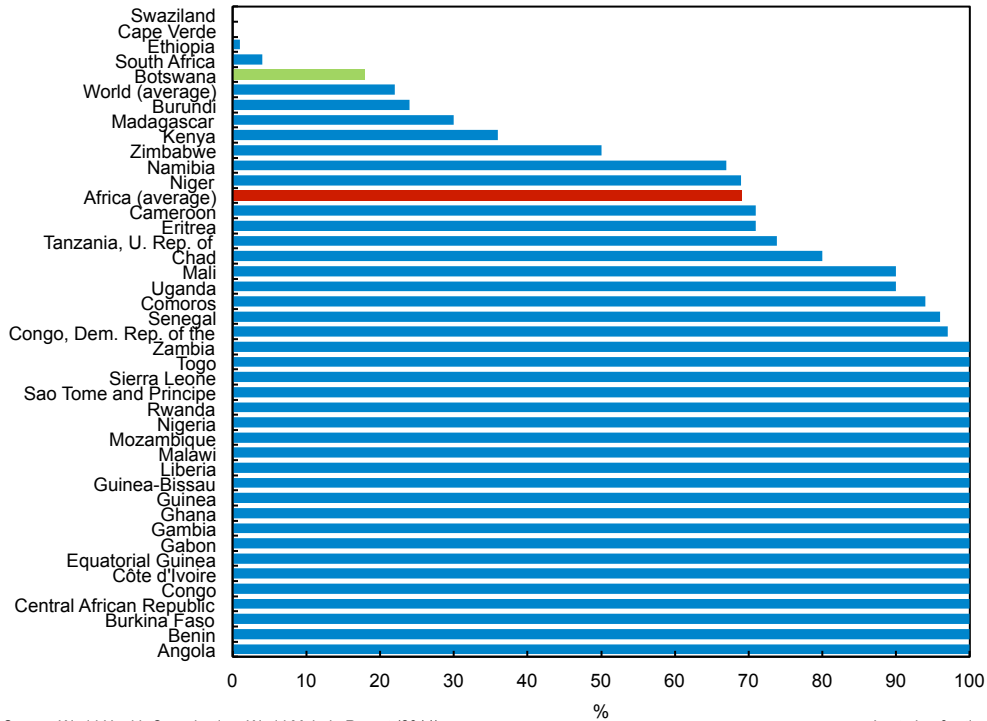
Source: Gallup and Sachs (2001), p.86.

Figure 7: The Malaria Transmission Cycle



Source: Gardner et al. (2005), p.506.

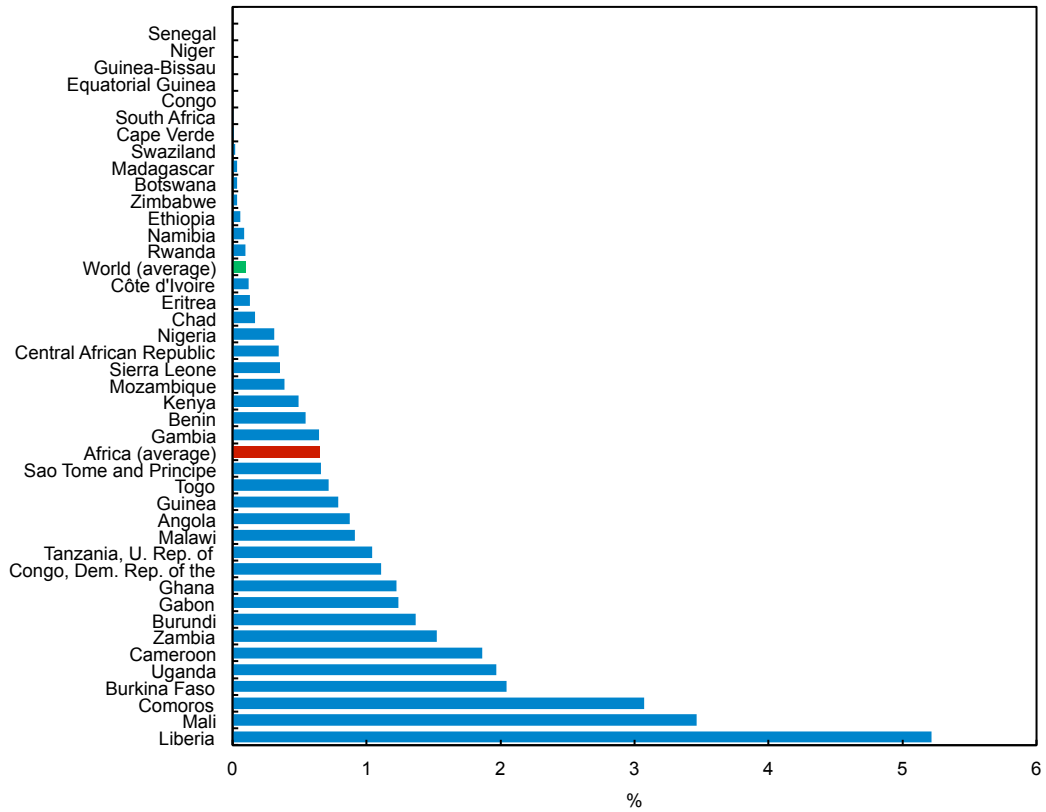
Figure 8: Percentage of the population at high risk of contracting malaria



Source: World Health Organization, World Malaria Report (2011)

Last observation: 2010

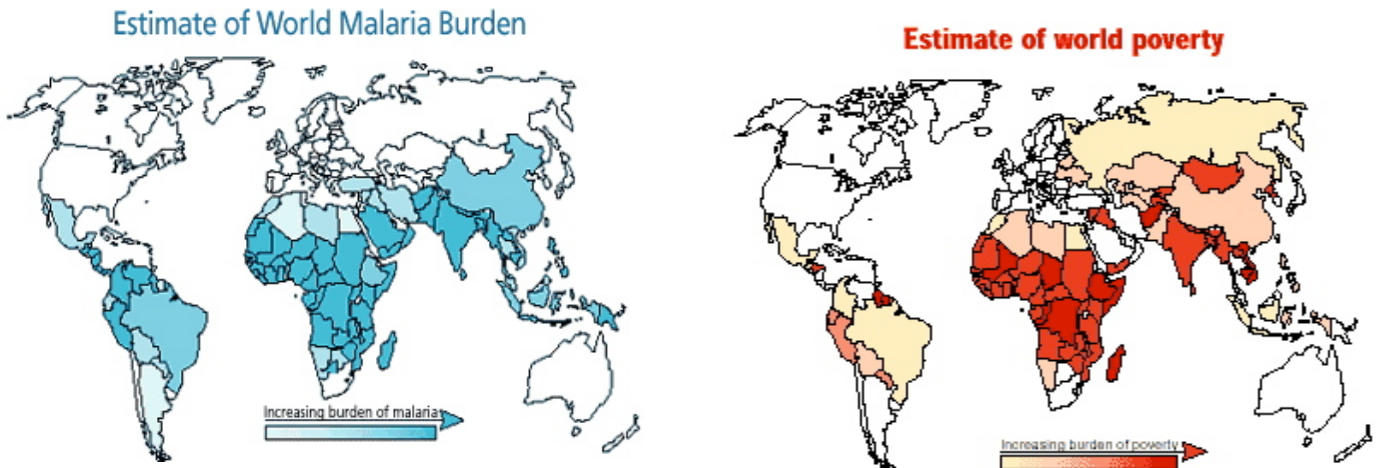
Figure 9: Percentage of the population that are inpatient malaria cases



Source: World Health Organization, World Malaria Report (2011)

Last observation: 2010

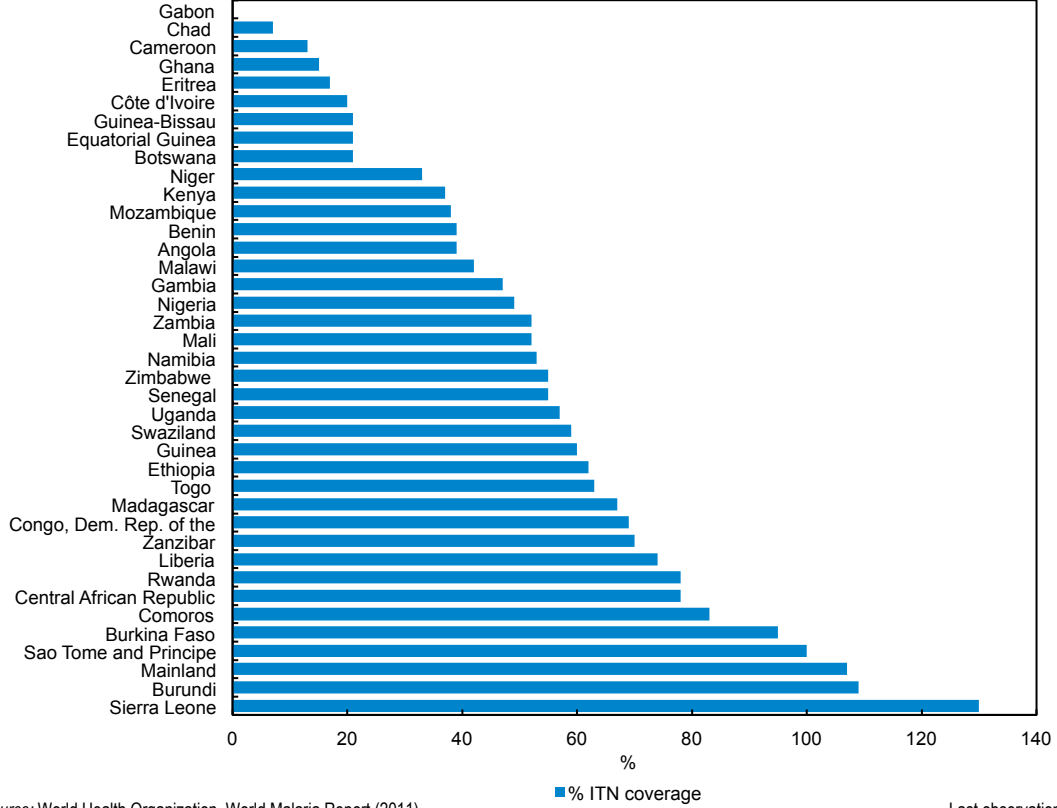
Figure 10: Estimate of World Malaria Burden and World Poverty



Source: Gallup, Sachs, and Mellinger (1999).

Figure 11: Percentage of ITN Coverage

% ITN Coverage, reported data for most recent year of the sub-saharan countries with available data

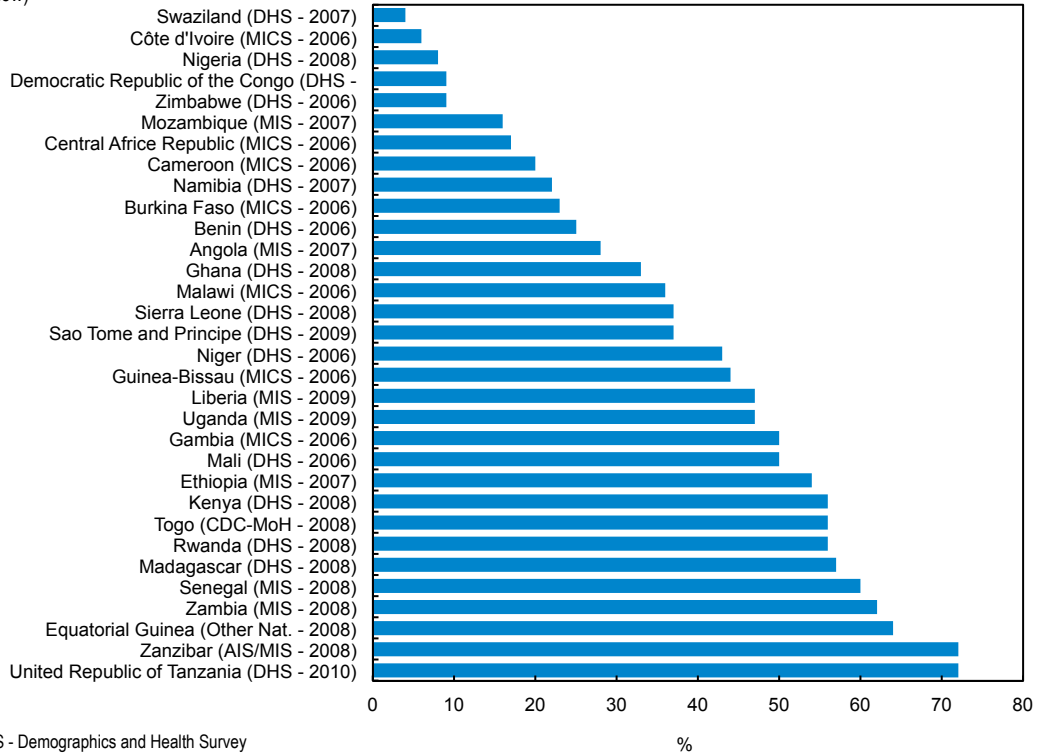


Source: World Health Organization, World Malaria Report (2011)

Last observation: 2010

Figure 12: Percentage of households owning more than one ITN

Reported data for most recent year of SSA available data (source and year of observations listed below)



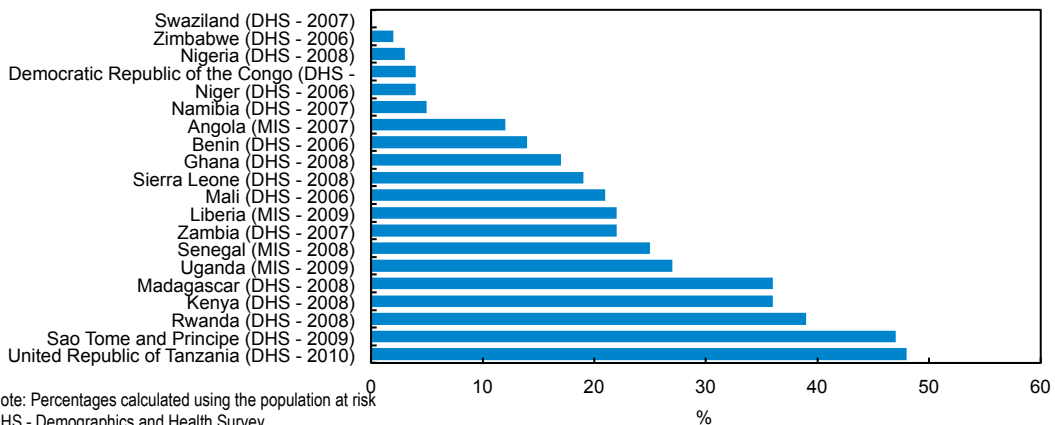
DHS - Demographics and Health Survey
MICS - Multiple Indicator Cluster Survey
MIS - Malaria Indicator Survey
Source: World Health Organization, World Malaria Report (2011)

■ % of HH with ≥ 1 ITN

Last observation:

Figure 13: Percentage of total population who slept under an ITN

Reported data for most recent year of the sub-saharan countries with available data (source and year of observation listed)



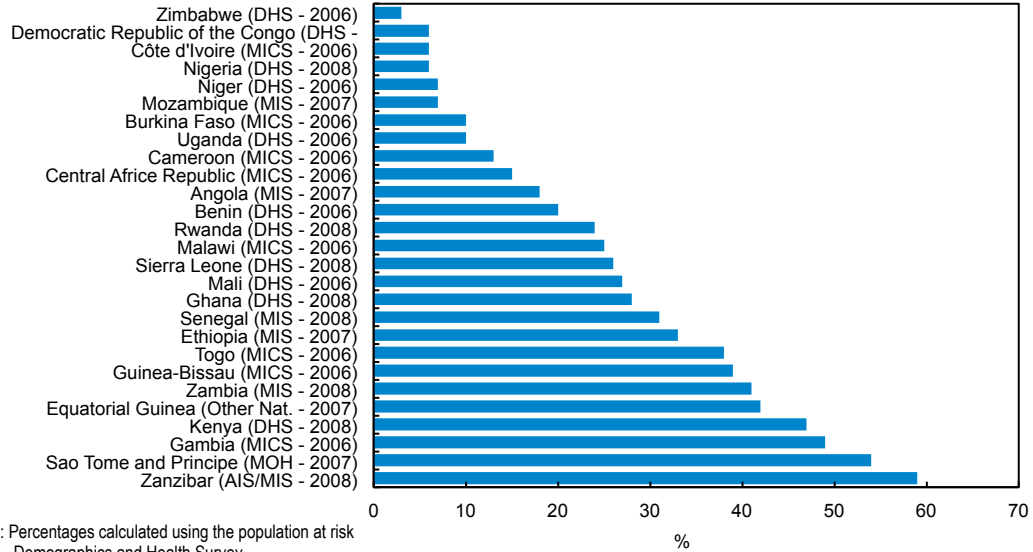
Note: Percentages calculated using the population at risk
DHS - Demographics and Health Survey
MICS - Multiple Indicator Cluster Survey
MIS - Malaria Indicator Survey
Source: World Health Organization, World Malaria Report (2011)

■ % Total population who slept under an ITN

Last observation:

Figure 14: Percentage of children under 5 who slept under an ITN

Reported data for most recent year of the sub-saharan countries with available data (source and year of observation listed)



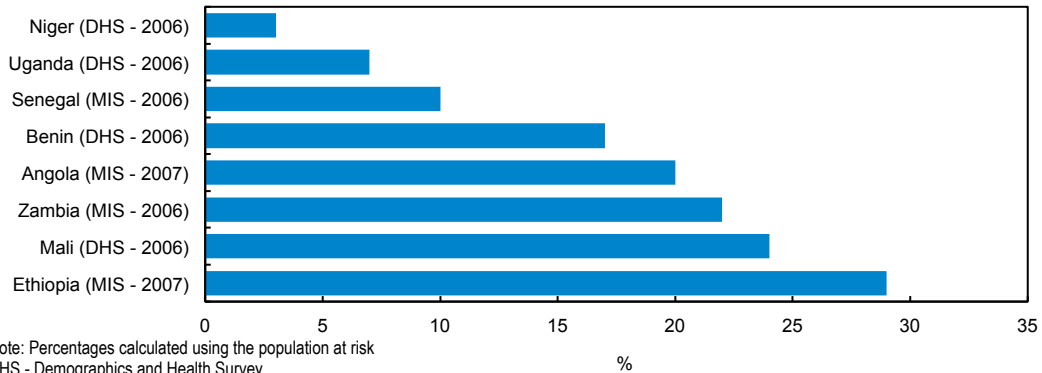
Note: Percentages calculated using the population at risk
 DHS - Demographics and Health Survey
 MICS - Multiple Indicator Cluster Survey
 MIS - Malaria Indicator Survey
 Source: World Health Organization, World Malaria Report (2011)

■ % of children <5 years who slept under an ITN

Last observation:

Figure 15: Percentage of pregnant women who slept under an ITN

Reported data for most recent year of the sub-saharan countries with available data (source and year of observation listed)



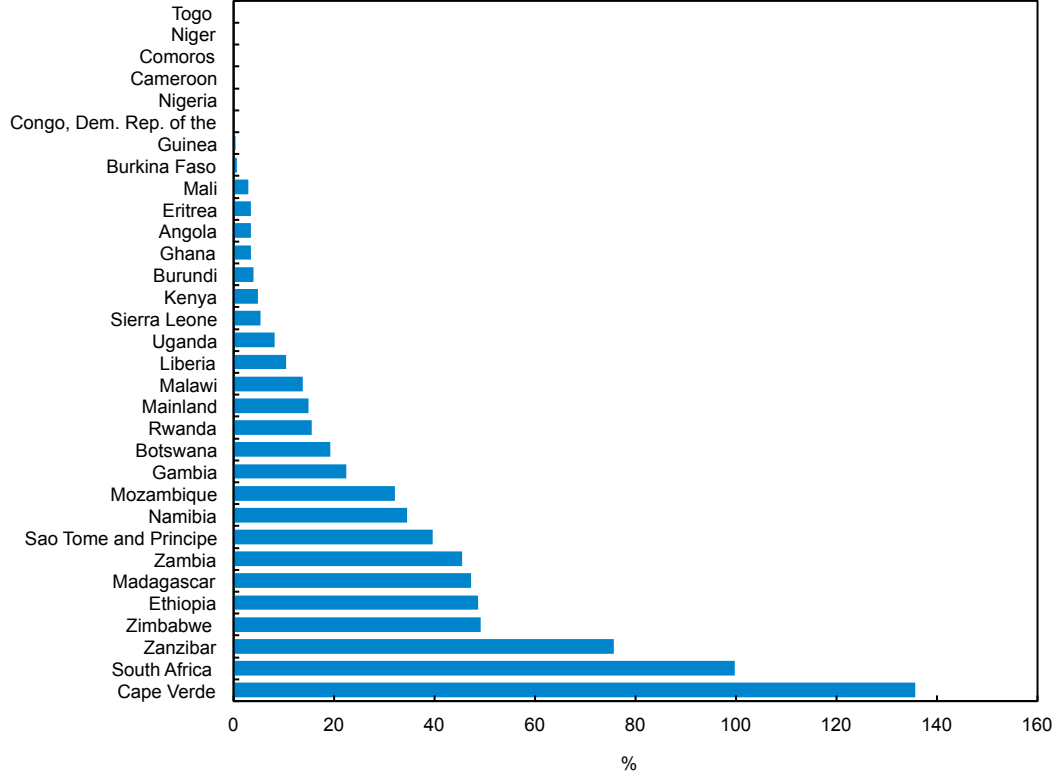
Note: Percentages calculated using the population at risk
 DHS - Demographics and Health Survey
 MICS - Multiple Indicator Cluster Survey
 MIS - Malaria Indicator Survey
 Source: World Health Organization, World Malaria Report (2011)

■ % of pregnant women who slept under an ITN

Last observation:

Figure 16: Percentage of IRS Coverage

% IRS Coverage, reported data for most recent year of the sub-saharan countries with available data



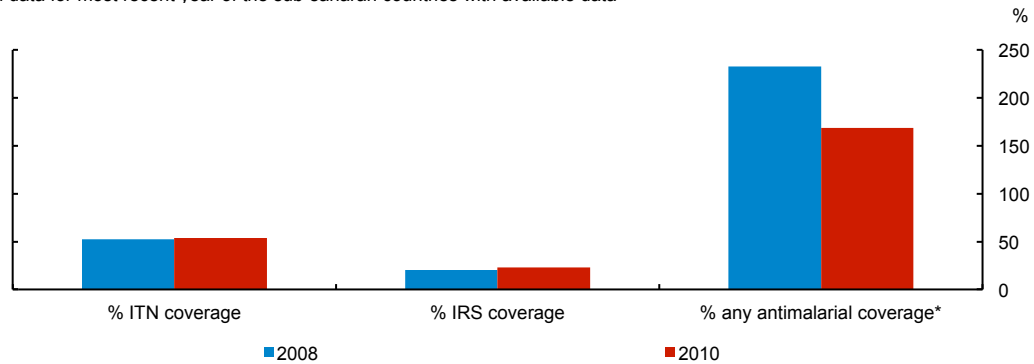
Source: World Health Organization, World Malaria Report (2011)

■ % IRS coverage

Last observation: 2010

Figure 17: Average malaria prevention coverage from 2008 to 2010

Reported data for most recent year of the sub-saharan countries with available data



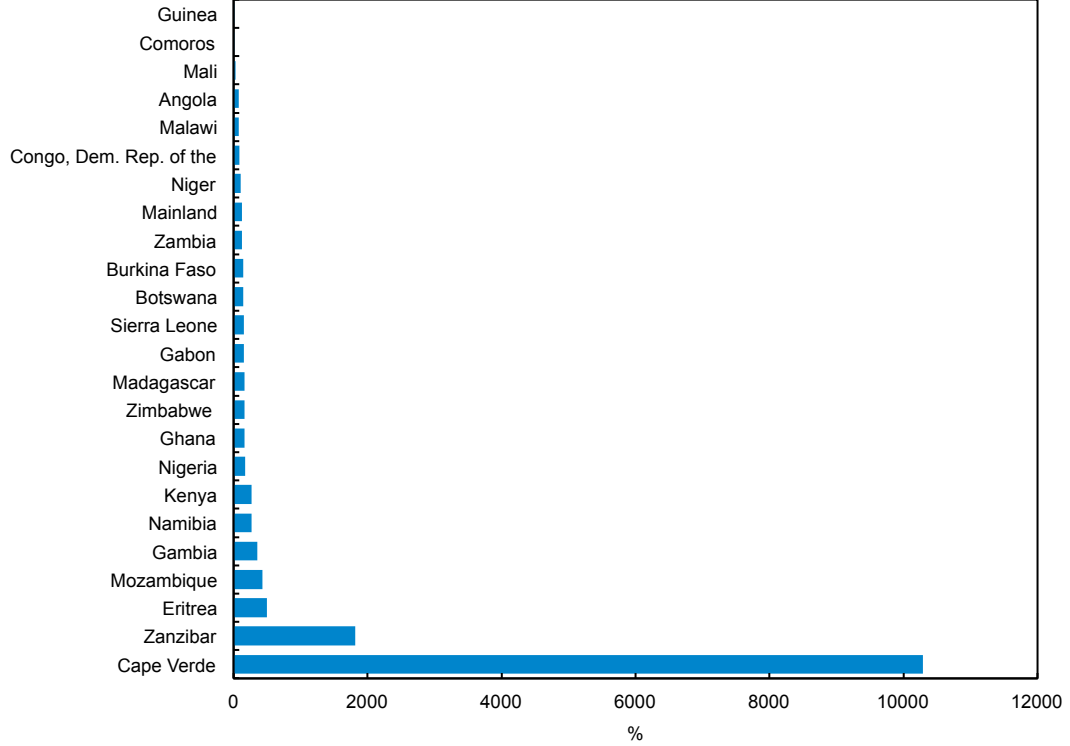
*Note: Based on Probable and confirmed cases adjusting for reporting completeness using 1st-line treatment courses delivered as proxy indicator for treated cases

Source: World Health Organization, World Malaria Report (2011)

Last observation: 2010

Figure 18: Total percentage of any antimalarial coverage

% any antimalarial coverage total, reported data for most recent year of the sub-saharan countries with available data



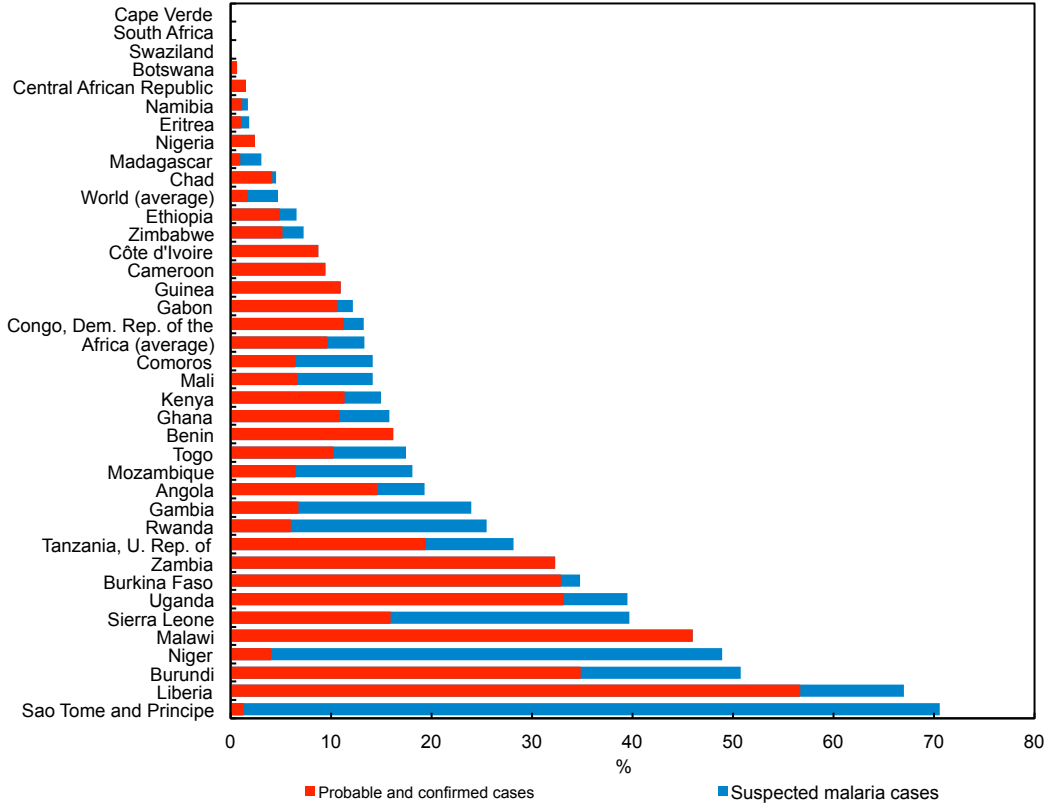
Note: Based on Probable and confirmed cases adjusting for reporting completeness using 1st-line treatment courses delivered as proxy indicator for treated cases.

Source: World Health Organization, World Malaria Report (2011)

■ % any antimalarial coverage

Last observation: 2010

Figure 19: Percentage of the population suspected to have malaria vs. confirmed cases



Source: World Health Organization, World Malaria Report (2011)

Last observation: 2010