Epidemiological Analysis of Malaria Decrease in El Salvador from 1955 until 2017

Tatiana I. Gardellini Guevara
University of South Florida

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Epidemiological analysis of Malaria decrease in El Salvador from 1955 until 2017

by

Tatiana I. Gardellini Guevara

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Public Health
College of Public Health
University of South Florida

Major Professor: Ricardo Izurieta, MD, DrPH, MPH
Ismael Hoare, PhD, MPH
Benjamin Jacob, PhD

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October 30, 2019

Keywords: plasmodium, elimination, control, epidemiology

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Dedication

I hereby dedicate this work to all those who have directly or indirectly contributed to the successful undertaken and completion of my endeavor in research.

No undertaking of mine can be ever complete without thanking my parents for being a fundamental pillar of my life, and having given me the support, the strength and the necessary motivation at all times. This is also an opportunity for me to thank my brother for always being with me and supporting me always.
Acknowledgments

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<tbody>
<tr>
<td>ACT</td>
<td>Artemisinin Combine Therapy</td>
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<tr>
<td>AMA</td>
<td>American Medical Association</td>
</tr>
<tr>
<td>AMI</td>
<td>Amazon Malaria Initiative</td>
</tr>
<tr>
<td>AMR</td>
<td>Anti-Microbial Resistant</td>
</tr>
<tr>
<td>BCC</td>
<td>Behavior Change Communication</td>
</tr>
<tr>
<td>BI</td>
<td>Breteau Index</td>
</tr>
<tr>
<td>CDC</td>
<td>The Centers for Disease Control and Prevention</td>
</tr>
<tr>
<td>CI</td>
<td>Container Index</td>
</tr>
<tr>
<td>DDT</td>
<td>Dichlorodiphenyltrichloroethane</td>
</tr>
<tr>
<td>DEET</td>
<td>Diethyltoluamide</td>
</tr>
<tr>
<td>DVS</td>
<td>Dominant Vector Species/Species Complexes</td>
</tr>
<tr>
<td>ELISA</td>
<td>Enzyme-Linked Immunosorbent Assay</td>
</tr>
<tr>
<td>G6PD</td>
<td>Glucose-6-Phosphate Dehydrogenase</td>
</tr>
<tr>
<td>GMAP</td>
<td>Global Malaria Action Plan</td>
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<tr>
<td>HI</td>
<td>House index</td>
</tr>
<tr>
<td>IAES</td>
<td>ABTI-Annual Blood Test Index</td>
</tr>
<tr>
<td>IPA</td>
<td>API-Annual Parasite Rate Standardized</td>
</tr>
<tr>
<td>ILP</td>
<td>Positive Slide Index</td>
</tr>
<tr>
<td>IEC</td>
<td>Information, Education and Communication</td>
</tr>
<tr>
<td>IFA</td>
<td>Indirect Fluorescent Antibody Assay</td>
</tr>
<tr>
<td>IRS</td>
<td>Indoor residual spraying</td>
</tr>
<tr>
<td>ITNs</td>
<td>Insecticide-Treated Bed Nets</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Full Form</td>
</tr>
<tr>
<td>--------------</td>
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<tr>
<td>MDGs</td>
<td>Millennium Development Goals 2015</td>
</tr>
<tr>
<td>MIGEVEC</td>
<td>Infectious Diseases and Vectors: Ecology, Genetics, Evolution and Control</td>
</tr>
<tr>
<td>MSPAS</td>
<td>Ministry of Public Health and Social Wellbeing</td>
</tr>
<tr>
<td>NADPH</td>
<td>Nicotinamide Adenine Dinucleotide Phosphate</td>
</tr>
<tr>
<td>NMP</td>
<td>National Malaria Programme</td>
</tr>
<tr>
<td>NMSP</td>
<td>National Malaria Strategic Plan</td>
</tr>
<tr>
<td>NVBDCP</td>
<td>The National Vector Borne Disease Control Programme</td>
</tr>
<tr>
<td>OMS-33</td>
<td>Ortho-isoproxyphenyl methylcarbamate</td>
</tr>
<tr>
<td>PAHO</td>
<td>The Pan American Health Organization</td>
</tr>
<tr>
<td>PCR</td>
<td>Polymerase Chain Reaction</td>
</tr>
<tr>
<td>PEM</td>
<td>Plan to Eliminate Malaria</td>
</tr>
<tr>
<td>PI</td>
<td>Pupae Index</td>
</tr>
<tr>
<td>PNAS</td>
<td>Proceedings of the National Academy of Sciences</td>
</tr>
<tr>
<td>QBC</td>
<td>Quantitative Buffy Coat</td>
</tr>
<tr>
<td>RDT</td>
<td>Rapid Diagnostic Tests</td>
</tr>
<tr>
<td>ULV</td>
<td>Ultra Low Volume</td>
</tr>
<tr>
<td>UMR</td>
<td>University of Montpellier</td>
</tr>
<tr>
<td>USAID</td>
<td>United States Agency for International Development</td>
</tr>
<tr>
<td>VC</td>
<td>Voluntary Collaborator</td>
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<tr>
<td>VCN</td>
<td>Voluntary Collaborator Network</td>
</tr>
<tr>
<td>VCP</td>
<td>Vector Control Program</td>
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<tr>
<td>WHO</td>
<td>World Health Organization</td>
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Abstract

The disease of malaria is complex, with clinical presentation that ranges from severe and complicated to mild and uncomplicated or even to asymptomatic malaria. A recent effort made by several world organizations has shown important advances in the effort to control and eradicate malaria. Following the general ordinance established by the trans-border organizations, each country has tried to define, according to their local geopolitical scenario, individual “road maps” to succeed in reducing the morbidity and mortality caused by malaria. Moreover, it is now accepted universally that these road maps need to be revised and appropriated in order to correct actions that allow fulfillment of the main goal: Control and eventual Eradication of Malaria.

In 2011, the Republic of El Salvador, a small Central American country, in coordination with international organizations, The Pan American Health Organization (PAHO) successfully launched and established at the national level, the Plan to Eliminate Malaria (PEM) which was conducted until 2014. According to the statistics El Salvador is positioned to cross into the final steps and get the certification that the disease has been eliminated from its borders. The general strategy of the PEM needs to be evaluated for its effectiveness and if necessary, revised to apply actions in the way of a Reorientation of the Program and this document is a proposal to fulfill this aim.

More than a century has elapsed since Levaran described the plasmodium as
micro-organismic species responsible for malaria along with Ross confirming their transmission by the female anopheles’ mosquito. However, malaria still remains a serious parasitic disease in the developing world resulting in high morbidity and mortality. Although the areas where transmission takes place have reduced over time, and they are by now confined to the inter tropical areas, the number of people living at risk has grown to about 3 billion, and is expected to go on increasing. It is reported that there are over 500 million cases every year, and between 1 and 3 million deaths. The disease also carries a huge burden that impairs the economic and social development of large parts of the planet.

Malaria's impact is felt at various levels, i.e. individual, national and global health care systems, that international organizations and national efforts are directed towards the control, and eventual elimination of the disease. Till, date however, they have been met with varying results. Developed parts of the globe like Europe and North America have succeeded in eliminating malaria from their shores whereas the disease still continues to afflict vast populations in Africa, Asia and South and Central America. These efforts, however, have met with varying degrees of success globally. Developed countries in Europe and North America have succeeded in eliminating malaria from their shores while the disease continues to afflict vast populations in Africa, Asia as well as South and Central America. This shows a regional variation in the success achieved in the fight against malaria dependent on development status and economic strength.

Malaria is believed to have reached the shores of the South America continent just over 500 years ago during the colonization, but it seems to have flourished in the existing favorable environs existing therein. The affected countries are approaching this problem
with individual and collaborative efforts with variable success.

Among these nations, the small Central American nation of El Salvador stands out as a frontrunner in efforts to eradicate malaria. As a matter of fact, the nation established the Program to Eliminate Malaria (PEM) spanning a period from 2001 to 2014 and according to the statistics is positioned to cross into the final steps and get the certification that the disease has been eliminated from its borders soon. This document is a retrospective data collection study of the incidence of malaria over two decades from 1994 to 2017 in order to evaluate the efficacy of the malaria control policy of El Salvador.

**Materials and Methods**

Data pertaining to incidence of malaria in El Salvador was collected for this research project conducted by the University of South Florida, College of Public Health, Department of Global Health in collaboration with the Ministry of Health and Social Wellbeing of El Salvador (MSPAS) and the Pan American Health Organization (PAHO) in El Salvador. Primary sources are comprised by the analysis of official documents from the MSPAS and PAHO in El Salvador. In addition, the databases at the National Epidemiology Surveillance System of the MSPAS were extracted and analyzed. As secondary sources specialized key malaria national and international experts were consulted about the subject.

**Results**

The collected data was subjected to the most appropriate data analysis. The obtained data was plotted on graphs of various axes and was evaluated for common or recurring themes as well as upward or downward trends. An attempt was made to isolate the factors that contributed towards success of the malaria program in El Salvador.
Discussion

The success story of the Central American Nation of El Salvador has proven itself to be a study model for the region and the world in the mission to eradicate malaria. In the final year included in this study more than half the reported cases were migrants from across the national borders. This according to us is an indication that the so called “endgame” in the fight against malaria is going to be as laborious and challenging as the pathway towards controlling it.

Conclusion

Thus, we may conclude that El Salvador is a shining example of a success story of fight against malaria that may be considered in its most vital and challenging chapter of transition from control to elimination, which, with the right strategy and execution might be a fairy tale ending that frees the country from malaria “ever after!”.
Chapter One: Introduction

More than a century has elapsed since Charles Louis Alphonse Laveran, a French army doctor described the *Plasmodium* as micro-organism species responsible for malaria along with Ross confirming their transmission by the female *Anopheles* mosquito (Carter et al., 2015; Lindbladen K.A., 2019; Navia, Tanner, Alonso, & Guinovart, 2006). However, malaria still remains a serious parasitic disease in the developing world resulting in high morbidity and mortality. Although the areas where transmission occurs have declined over time and are by now confined to the inter tropical areas, the number of people currently living at risk has increased to about 3 billion, and it is expected to continue increasing (Navia et al., 2006). It is reported that there are over 500 million cases every year, and between 1 and 3 million deaths. The disease also carries a huge burden that impairs the economic and social development of large parts of the planet (Navia et al., 2006).

Being malaria a disease that produces a high burden on national and global health care systems, several international organizations and nations have directed their efforts towards the control and eventual elimination of the disease. Till, date however, these goals have been met with varying results. Developed countries in Europe and North America have succeeded in eliminating malaria from their shores. However, the disease still continues to afflict vast populations in Africa, Asia, and South and Central America.
Malaria is believed to have landed in the shores of the South America continent just over 500 years ago with the colonization, but seems to have flourished in the existing favorable environs existing therein (Griffing SM, 2015). The affected countries are approaching this problem with individual and collaborative efforts with variable success (Yalcindag et al., 2012).

In the Americas, malaria cases substantially decreased during the period 2001-2011 with three Central American countries, Mexico, Costa Rica and El Salvador, entering the pre-elimination phase (Carter et al., 2015). Among these countries, the small nation of El Salvador stands out as a front runner in efforts to eradicate malaria. El Salvador established the Program to Eliminate malaria (PEM) spanning a period from 2001 to 2014. According to the statistics the country is positioned to cross into the final steps to certify that the disease has been eliminated from its borders.

There have been various factors that have determined increases and declines of the malaria cases in the Americas. In the 1950s, when the malaria Eradication Program was established, the substantial increase in cases was determined by improvements in the detection of cases. A second spike observed in the 1970s most likely was associated with the development of resistance to insecticides by Anopheles spp. as well as by the development of chloroquine resistance by Plasmodium falciparum. Later in the 1980s the presence of natural disasters like Hurricanes David and Federico in 1979 (Steinberg, 2016), as well socio-political conflicts like the civil wars in Nicaragua, Guatemala and El Salvador determined a substantial increase in malaria cases. The expansion of agricultural areas as well as the introduction of new agroindustry species like oil palm and
bananas in Central America also contributed to the increases reported by Costa Rica and other countries of this region (Carter et al., 2015).

On the other hand, tremendous advances in the control and elimination of malaria in the Americas were achieved by the improvement of socio-economic conditions of its populations and investments in vector control, such as the elimination of malaria from the United States territories in the 1950s (CDC, 2019). Other factors that contributed to the control of this disease have been the improvements in the detection and surveillance supported by the Global Fund for AIDS, tuberculosis and malaria (Global Fund). The economic and technical support provided by the United States Agency for International Aid (USAID), United States Centers for Disease Control, and Pan American Health Organization through the Amazon Malaria Initiative (AMI) were crucial for the achievement of the Millennium Development Goals 2015 (MDGs) (Carter et al., 2015). In 2000, the introduction of artemisinin combined therapies for the treatment of Anti-Microbial Resistant (AMR) malaria was crucial for the control and elimination of *P. falciparum* in vast territories of the region. Another critical factor in the control and elimination of malaria in the Americas it has been the decentralization of the clinical management of malaria by the training of community health workers in the diagnosis and treatment of malaria. Timely malaria diagnosis and treatment within the first 48 hours has been described as stopping the emergence of sexual forms of the parasite in blood (Reina-Ortiz, 2015). Most recently, another threat has emerged in Guyana and Surinam where it has been reported resistance of the parasite to the efficacy of artemisinin combined therapy (PAHO, 2013).
Thus, although malaria continues to be a significant burden to humanity over the ages, here are cases where it has been convincingly overcome. Recently, the winners against this malaria fight were limited to developed regions of the globe while the developing and underdeveloped or young nations continued to struggle due to geographic and economic circumstances. El Salvador, however, seems to emerge as a young nation, within the high incidence belt that even with a developing economy has been able to control malaria within its borders. This emergence presents an interesting study to examine the country’s malaria program that is over half a century old and has proven to be durable, effective and successful especially over the last two decades.

In summary, socioeconomic conditions, changes in health policies, environmental changes, development of antimicrobial and insecticide resistance have negatively impacted the control and elimination of malaria in the Americas. On the other hand, introduction of Artemisinin Combine Therapy (ACT), decentralization of malaria cases management with timely diagnosis and treatment as well as international cooperation have positively impacted by decreasing the incidence of the disease.

This document is a retrospective data collection study of the incidence of Malaria over two decades from 1994 to 2013 in order to evaluate the efficacy of the malaria control policy of El Salvador. This analysis of the good practices and good experiences in malaria control carried out by El Salvador aims to place the strategies implemented as a model to control the disease in other countries and other continents.
Chapter Two: Historical Background

Malaria is considered to be an ancient affliction plaguing mankind. With references to intermittent fevers termed as “ague” (a popular abbreviation for chills and fever attributable to malaria), it can be identified in several Biblical passages (Bollet, 2004). The same were also mentioned in the writings of Hippocrates (400 BC) (Cunha & Cunha, 2008). Physic evidence of malarial disease has been detected in Egyptian mummies in 800 BC (5), and even before the Greek and Egyptian civilizations, it was described in the Chinese pharmacological report “Huangdi Neijing, Inner Casnon of the Yellow Emperor” written between the Chun Qiu and Qin Dynasties, 770–207 BC (Tu, 2016). In addition, Indian writings of the Vedic period (1500 to 800 BC) called malaria the “king of diseases” (KJ Arrow, C Panosian, & H Gelband, 2004)

World

In the modern history, malaria is believed to have originated in the African rain forest, from where the disease most likely traveled down the Nile to the Mediterranean, then spreading eastwards to the Fertile Crescent, and north to Greece. Greek traders and colonists are supposed to have brought it to Italy. From there, Roman soldiers and merchants ultimately transported it as far north as England and Denmark (Karlen, 1996).

Over the next two millennia, wherever Europe harbored crowded settlements and standing water, malaria flourished, rendering people seasonally ill, and chronically weak
and apathetic. It is speculated by historians that falciparum malaria -the deadliest form of malaria species in humans- contributed to the fall of Rome, the capital of the Roman empire. The malaria epidemic of 79 AD devastated the fertile, marshy croplands surrounding Rome, causing local farmers to abandon their fields and villages (Cartwright & Biddiss, 2000).

In India and China, population growth drove people into semitropical southern zones especially around fertile river beds that favored malaria (Tu, 2016). Migrants from the dry Indus valley to the hot, wet Ganges valley to the south were disproportionately plagued by malaria along with other mosquito-borne and water-borne diseases. Likewise, in China, millions of peasants who left the Yellow River for hot and humid rice paddies bordering the Yangtze encountered similar hazards (KJ Arrow et al., 2004).

Central and South America

A large international study recently published in the Proceedings of the National Academy of Sciences (PNAS) by scientists from the UMR MIVEGEC (Infectious Diseases and Vectors: Ecology, Genetics, Evolution and Control, France) and their partners has shown that *P. falciparum* may have crossed the Atlantic on slave ships between the 16th and the 19th century, some 500 to 200 years ago. The research team has indeed just demonstrated that the parasite which is now found in America has African origins. This study has also shown that *P. falciparum* colonized the American continent through two independent introduction routes. The biologists have identified two separate genetic groups of *P. Falciparum* in Latin America, one in the North and the other further South. Both of these entities are genetically closer to the African source than to each other. Due to their geographical segregation by the Andes, these species of Falciparum have
evolved separately from each other over time (Yalcindag et al., 2012).

Regarding *P. vivax*, it has been described as an evolutionary jump from no human anthropoids to humans which happened in East Asia when rice and millet were domesticated. The genetic heterogeneity of *P. vivax* makes us believe that there have been various introductions of this parasite into de Americas. Most likely, the first introduction happened when the Asian populations crossed the Bering Straits to populate the American continent approximately 15 to 30 thousand years BC. A second wave of introduction of *P. vivax* into de Americas happened during the European immigration initiated by Columbus in 1492 and later during the slave trade (Taylor et al., 2013).

**El Salvador**

The historical account of malaria in El Salvador begins in the early nineteenth century. Located on the Pacific coast of Central America, El Salvador´s landscape consists of two mountainous highlands, transecting the country from east to west separated by a wide interior valley opening out to the south and the east into a narrow coastal plain along the Pacific Ocean.

History is replete with examples where industrialization and consequent population concentration has led to outbreaks of diseases including malaria. El Salvador surprisingly, is an exception to the trend by successfully managing a positive control of malaria with the advent of industrialization and establishment of the cotton belt. El Salvador joined other countries in Central America in an effort to eradicate malaria from the Americas in the 1957. At the time, nearly the entire country was defined as malarious (Chevez, 2019).

Yet, in most of the highland areas of the country Malaria was unstable and was in fact easily reduced in a couple of years. By 1964, extensive residual spraying with Dichlorodiphenyltrichloroethane (DDT) largely eliminated malaria from areas above 650 feet. By the 1970s, majority of the cases occurred in areas below 300 feet in the central valley and along the Pacific Coast. However, the movement of individuals between the lowlands and highlands often triggered flare-ups in the higher altitudes, and successive efforts during the 1970´s to eliminate the remaining pockets of malaria met with little success, primarily due to the development of the “cotton belt”. However, as compared to neighboring countries, El Salvador fared much better principally due to control of nurseries of vectors by means of drains and use of larvicides (Chevez, 2019).

Beginning in 1980, El Salvador´s Malaria Control Program, with the assistance of advisors from the U.S. Public Health Service, initiated an Integrated Malaria Control Program, which was a four-pronged action plan of: 1.-Improved and prompt access to effective treatment, 2.-Increased use of locally appropriate means of mosquito control, 3.-Early detection of and response to malaria epidemics, 4.-Improved prevention and treatment of malaria in pregnant women, following the guidelines established by the World Health Organization (Anderson, 2009).
The next decade in El Salvador was marred by civil war and its repercussions that reversed the effects of the preceding malaria control programs. However, the situation progressively and gradually improved into the new millennium putting El Salvador back into its position as the frontrunner for malaria control in the Central American region. In fact, El Salvador was recognized by one of the Malaria Champions by PAHO in 2016 (Chevez, 2019).

This goes to show that the malaria program of El Salvador has gone through a visible evolution over the last few decades. Several factors played an important role in the formulation, implementation and sustenance of the program. Salient features of this were alignment with the WHO, support from United States CDC and USAID, industrial revolution, civil war and program formulation. All these factors eventually culminated into the position that El Salvador has reached in its control of malaria in the present day. We can summarize this chapter by describing one main introduction of \( P. falciparum \) into the Americas during the colony slave trade and various introductions of \( P. vivax \), happening the first introduction when Asian populations immigrated into de Americas crossing the Bering Straits. The history of malaria in the El Salvador republic can be synthetized in five distinct historical time periods pertaining to malaria incidence until now: 1955-1969: Global Eradication Campaign; 1970-1980: Resurgence; 1981-1995: Rapid Decline; 1996-2011: Continued Decline; and 2011 till date: Endgame (Chevez, 2019).
Chapter Three: The Disease

Definition

The 2017 updated definition of malaria by WHO states that malaria is a preventable and curable disease caused by plasmodium parasite that are transmitted to people through the bites of the infected *Anopheles* spp. mosquito and is characterized by acute febrile illness that may develop into morbid or mortal complications in high risk groups thereby exerting heavy global disease burden (WHO, 2019a).

Causative organism

Malaria in humans is caused by five species of the Plasmodium protozoa: *P. falciparum*, *P. vivax*, *P. ovale*, and *P. malariae* and the recently reported *P. knowlesi*. Infected humans are the only reservoir for the first four plasmodial species and all five infect humans and transmission occurs through the bite of infected female anopheline mosquitoes. The last plasmodia, *P. knowlesi*, a less common form of human malaria has recently been attributed to a monkey zoonotic disease. These zoonotic cases occur in forested areas of Southeast Asia where the other species of human malaria may be absent (Schaechter, 2017).
Vector

Human malarial protozoa are transmitted by mosquitoes of the genus *Anopheles* that consists of 465 formally recognized species and over 50 unnamed members of species complexes. Approximately 70 of the recognized 465 species have the ability to transmit human malaria parasites while 41 of them are considered dominant vector species/species complexes (DVS), with capability of transmitting malaria at a level that can prove to be a major concern to public health (Sinka et al., 2012).

Figure 1. A global map of dominant malaria vector species

Source: Sinka et al. Parasites & Vectors 2012, 5:69
Figure 2. A regional map showing the distribution of nine DVS across the Americas

Source: Sinka et al. Parasites & Vectors 2012, 5:69
Figure 3. A map showing a closer view of the complexity and diversity of the distribution of eight DVS in Central America and in the northern regions of South America.

Source: Sinka et al. Parasites & Vectors 2012, 5:69
Cycle

Regarding the cycle of transmission of *Plasmodium* spp in its natural environment, the *Anopheles* spp vector inoculates into the human host the parasite while it is feeding. Female mosquitoes need to feed of blood for oviposition and they inject the parasite in its sporozoite form. The sporozoite forms in a matter of minutes reach the liver where they develop into hepatic schizonts. These hepatic schizonts burst releasing between 2 to 40 million merozoites. In the case of *P. vivax* and *P. ovale*, the development into hepatic schizont may take up to 2 or 2 years. This long-term permanence of *P. vivax* and *P. ovale* is called the dormant stage of the parasite which makes the human host a long-term reservoir. Immediately after the merozoites area released from the liver, they move to find a red blood cell in which they will mature into erythrocytic schizonts. Within the red cell, the merozoite matures either into trophozoites.

![Figure 4. The malaria parasite life cycle](image)

Source: Centers for Disease Control and Prevention
(asexual cycle) or a uninucleate gametocyte (sexual cycle). The asexual forms mature into an erythrocytic stage schizont containing 10 to 36 merozoites. Rupture of the schizont releases these merozoites, which infect other red cells. On the other hand, the sexual forms, if ingested by the vector mosquito, the female and male gametocytes undergo into fertilization in the mosquito gut, and then mature in 2 to 3 weeks to become sporozoites (Hoffman S, 2011; Schaechter, 2017).

**Human Genetics and Malaria**

Genetic polymorphism of several human genes affects the entry, multiplication, and survival of malarial parasites. Genes are also important in the determination the overall outcome of the infection. For example, parasite invasion of red blood cells depends on the presence of specific surface molecules. For *P. falciparum* and *P. vivax*, the surface molecules are glycophorin A and the Duffy blood group antigen, respectively. The variable susceptibility of African Americans to *P. vivax* infection is consistent with the distribution of Duffy antigen. Other genetic abnormalities that restrict the growth of malarial parasites within red blood cells are glucose-6-phosphate dehydrogenase deficiency (G6PD) and thalassemia. In the case of G6PD, the reduced ability of the red blood cells to produce Nicotinamide Adenine Dinucleotide Phosphate NADPH via the pentose phosphate shunt is thought to cause an oxidative stress that inhibits parasite growth (Schaechter, 2017).

**Management**

*Clinical Diagnosis*

When the merozoites invade the erythrocytes, the temperature of the body increases producing fever, which is the main sign of malaria. Other symptoms that accompany fever include headaches, chills, myalgias, nausea and vomiting. They can also be observed with less frequency symptoms like abdominal pain, diarrhea, and cough.
The classical malaria paroxysm is characterized by different phases that include: 1. A cold stage that lasts for 15 to 60 minutes with shivering, 2. Then the fever is presented with temperatures as high as 41°C and lasts for 2 to 6 hours. As mentioned, the fever is accompanied by headaches, dry skin, nausea and vomiting. Ultimately, a 2-to-4 hours sweating stage during which the fever drops rapidly and the patient sweats signaling the end of the paroxysm (Hoffman S, 2011). In all types of malaria, the periodic febrile response is caused by rupture of mature schizonts. In the malaria caused by *P. vivax* and *P. ovale* malaria, a brood of schizonts is known to mature over a period of every 48 hours, thereby resulting in a periodicity of fever that is tertian ("tertian malaria"), while on the other hand, in the disease caused by *P. malariae*, the fever emerges every 72 hours and it is called "quartan malaria". In the case of *P. falciparum*, the fever may be irregular or occur every 28 hours, which evidences a lack of periodicity. These types of classical paroxysmal patterns of fever are commonly not seen initially in the course of malaria, and therefore the absence of periodic, synchronized fevers does not rule out a diagnosis of malaria (Crutcher & Hoffman, 1996; Hoffman S, 2011).

*Laboratory (Biological) Diagnosis*

In 1904, Gustav Giemsa introduced a mixture of methylene blue and eosin stains. Microscopic examination of Giemsa-stained blood smears has subsequently become the gold standard of malaria diagnosis (Woods & Walker, 1996).

In the past 50 years, alternative methods became available (e.g., detection of malaria antibodies by indirect fluorescent antibody assay (IFA) and enzyme-linked immunosorbent assays (ELISA). Later, scientists developed methods to detect malaria antigens, the most significant being the immunochromatographic assay, which forms the basis of commercial malaria Rapid Diagnostic Tests (RDT’s) available today (Hoffman S,
Molecular methods, namely, DNA probes and polymerase chain reaction (PCR) were introduced in the 1980s–1990s. Methods for detecting malaria parasites by fluorescent staining also emerged (e.g., by the quantitative buffy coat (QBC) analysis, interference filter system for acridine orange-stained thin blood smear, and flow cytometry). Detection of malaria pigments by depolarized laser light and mass spectrometry showed limited success (Hoffman, 1992; Zheng & Cheng, 2017).

Although molecular parasitology methods have emerged as highly specific and sensitive methods for the diagnosis of malaria, standard simple microscopy is still considered the gold standard in the clinical diagnosis of this disease. Nevertheless, the low sensitivity of standard microscopy in the diagnosis of chronic low parasitemia cases has created the need of introducing colorimetric monoclonal techniques which can be done in the field with low technology (Ravaoarisoa et al., 2017).

**Clinical Management**

Clinical management of malaria involves symptomatic management as well as pharmacological intervention (Hoffman S, 2011). As mentioned, the gold standard method for malaria diagnosis is simple microscopy and the algorithm used in the United States is also used in other countries; however, the treatment may vary due to the availability and cost of antimalarial drugs. The American Medical Association (AMA) gives the following guidelines for effective management the disease (Figure 5).

**Complications**

*P. falciparum* malaria is a medical emergency that has to be taken care immediately. If the malaria diagnosis is delayed or missed, serious complications and even death may occur. Among the most serious complications of malaria we can mention
cerebral infection and anemia. In cerebral malaria the patient is lethargic with mental disorientation. Cerebral malaria has a case-fatality rate as high as 15 to 50%. Among other complications we can mention a severe hypoglycemia, a severe hypoxia that can complicate with a lactic acidosis. The prolonged hyperthermia can derivate into shock. Other complications include cardiac, pulmonary, renal and liver failure. The renal complication is called disease of the “black waters” due to the characteristic dark color of the urine. Liver failure may cause bleeding problems and cerebral infection can cause seizures. Sever vomit and diarrhea can complicate with hematemesis and melena. All these malaria complications make a poor prognosis of the patient. Groups at risk of complications and death include elderly, children, immunodeficient persons, pregnant women, as well as those with chronic diseases. These complications may also include sepsis, pneumonia caused by aspiration, and splenic rupture (Crutcher & Hoffman, 1996).

In summary, we can mention that the presence of more than 465 species of Anopheles spp. mosquito species make the vector control challenging in order to stop the transmission of this disease. In the past four exclusively human Plasmodium spp. have been described, but recently a fifth zoonotic monkey-human malaria has been reported the rainforests of Malaysia. The clinical presentation makes it possible the differentiation between tertian (P. vivax and P. ovale) and quartan malaria (P. falciparum and P. malariae). Although molecular techniques have been developed for the diagnosis of the disease, still simple microscopy continues being the gold standard method.
Figure 5. Malaria Treatment Algorithm

Source: (Griffith KS, 2007)
Chapter Four: Control, Elimination and Eradication

Preventing or reducing malaria transmission depends entirely on control of the mosquito vectors or interruption of human–vector or elimination of human reservoir by treatment of the parasitemia. In the 1950 WHO proposed the eradication of malaria in the Americas; but in 1969, the same WHO changed its strategy for the control of the disease considering the increasing costs of insecticides and antimalarial drugs due to the development of *Plasmodium* spp. and *Anopheles* spp. resistance (Shretta R, 2017).

Malaria eradication is the permanent reduction of the disease to zero prevalence and zero incidence among humans. Once the world eradication is achieved, all control interventions should be ceased. Elimination of the disease is the interruption of the transmission in a country or defined geographic region; therefore, no indigenous cases should be reported, and it may happen imported cases. Malaria control is the reduction of the morbidity and mortality of the diseases as well as the reduction of its incidence and prevalence. Interventions should be long term maintained to keep the disease under control (Shretta R, 2017).

As mentioned malaria control has been defined by the WHO as the process for reducing the disease burden to a level at which it is no longer a public health problem (WHO, 2009). There are three levels of control of malaria: Primary, Secondary, and Tertiary.
Primary Prevention and Control

Primary prevention is concerned with preventing the onset of disease; it aims to reduce the incidence of disease. It involves interventions that are applied before there is any evidence of disease or injury. The primary level of prevention involves the interaction between the Host and the Vector.

Host Factors

Vaccine: Although vaccination is one of the primary means of primary control and prevention of a disease, the vaccine for malaria is still in its developmental phase. Nevertheless, the malaria genome mapping recently has raised the hopes of developing an effective vaccine in the impending future. Field testing of new vaccines is ongoing and is expected to revolutionize the fight against malaria (WHO, 2019b). At this moment, the general approach is that any available vaccine should be used as a complementary measure in the primary prevention of malaria. This means that the malaria control should be carried with an Integrated Malaria Control approach along with tools from all three levels of prevention. Moreover, successful programs only function if malaria control tools and technologies are assumed by visionary and with sufficient global financial resources (Shretta R, 2017).
Behavioral change: The strategy of use of behavior change communication (BCC) is based on the application of targeted messages and tailored approaches to promote healthy behaviors and reduced risk taking. BCC which is also known as social and behavior change communication, as an entity encompasses health communication, social and community mobilization, and has evolved from strategies of information, education and communication (IEC). The public is advised to avoid going out between dusk and dawn when anopheline mosquitoes commonly bite, if venturing outdoors to wear long sleeved clothing and avoid using dark colors which attract mosquitoes (Koenker et al., 2014). One example of the relevance of the behavioral interventions is the impact of training on compliance with the used of Insecticide Treated Bednets (ITB) (Krezanoski et al., 2019). Also, behavioral interventions have been proved to be crucial in the adherence to malaria treatment (Camara et al., 2019).

Improvements in host resistance: Some population groups are at considerably higher risk of contracting malaria, and developing severe disease, than others. These primarily include infants, children under 5 years of age, pregnant women, malnourished adults and patients with HIV/AIDS, as well as non-immune migrants, mobile populations and travelers. It is the onus globally that all National malaria control programs should undertake take additional measures to safeguard these population groups from malaria, by giving due consideration to their specific circumstances (WHO, 2015). Programs for malaria control have mentioned the importance of improving the nutritional status of malaria endemic populations in order to improve the capacity of the host immune system to cope with the infection. For example, Zinc has been proved to be crucial micronutrient
to have a robust immune response to Plasmodium spp. In children. Therefore, interventions improving the nutritional status and providing micronutrient supplementation have been recommended (Ackland & Michalczyk, 2016).

Barrier methods: Use of barriers are the control options against the adult mosquito. Insecticide-treated material can be used in implements such as Insecticide-treated bed nets (ITNs), bed sheets and clothing. However, these require retreatment biannually which might create a compliance issue (Curtis, Jana-Kara, & Maxwell, 2003; Rowland et al., 1999; Seyoum et al., 2012). One of the main recent advances it has been the use of Long-lasting insecticidal nets (LLIN) which have had a tremendous impact in decreasing prevalence and incidence of the parasitemia. Nevertheless, the development of resistance to pyrethroids by the Anopheline mosquitos is placing at risk of becoming useless the implementation of this control method (Ranson et al., 2011).

Other: Other methods include use of insect repellents such as The most effective repellents contain diethyltoluamide (DEET) and are available in sprays, roll-ons, sticks and creams (Robert LL, 1991). Also, innovative integrative control methods have been proposed, like the combination of the conventional and serology testing with geospatial models to produce accurate prevalence and incidence maps at high resolution scales which has made more efficient the malaria control interventions (Corran, Coleman, Riley, & Drakeley, 2007).
Vector Factors

Vector governed factors of primary prevention and control of malaria include:

Biological control:

Figure 6. Mosquito biocontrol strategies targeting different stages of the mosquito lifecycle

Source: Benelli, G 2016
Elimination of breeding sites / Source reduction: Source reduction is removal or permanent destruction of mosquito breeding sites. The known habitats of the larva can be destroyed by filling depressions that accumulate water, by drainage of swamps or by undertaking ditching of marshy areas to eliminate standing water. Mosquitoes that breed within containers are especially susceptible to the process source reduction as people are able to remove or cover standing water in cans, cups, and rain barrels around houses. Mosquitoes that breed in irrigation water can be controlled through careful water management (CDC, 2019).

Insecticides for larvae: For some mosquito species, habitat elimination is not possible. For species such as these, chemical insecticides can be applied directly to known larval habitats. Other less disruptive methods which are safer to the environment, are usually preferred such as: Oils that can be applied to the surface of the water thereby suffocating the larvae and pupae. Most oils in use currently are biodegraded rapidly. Toxins that are isolated from the bacterium Bacillus thuringiensis var. israelensis (Bti) are utilized in the way similar to chemical insecticides. These toxins are very specific to affect solely larvae of mosquitoes, black flies, and midges. Also, antagonist of insect growth hormone has been used to stop the maturation of the larvae into pupae. Insect growth regulator such as methoprene which are specifically toxic to mosquitoes can be applied in the way similar to the chemical larvicides (CDC, 2019; Darabi, Vatandoost, Abaei, Gharibi, & Pakbaz, 2011; Jindra & Bittova).
Insecticides for adult Mosquitoes: 1.-Outdoor Control, outdoor control of adult malarial vector mosquitoes is achieved by Ultra Low Volume (ULV) Spraying under commission of Governmental agencies; 2.- Indoor Control, Indoor control is achieved by insecticide spraying inside houses e.g. Permethrin. Insecticide-treated bed nets combine vector control and personal protection. One of the main tools to control malaria. Clothes can also be impregnated with permethrin. (Yakob, Cameron, & Lines, 2017). In addition, insecticide-treaded hammocks (Magris et al., 2007) and house paint mixed with insecticides (Ngufor et al., 2014) are new more environment friendly vector control strategies.

Management of Infected Humans

The primary control and prevention of malaria in terms of infected human hosts include: 1.- Antimalarial Therapy and, 2.-Isolation and quarantine.

Antimalarial Therapy: It is important to institute effective and complete antimalarial therapy in known human hosts of malaria in order to control the persistence of human reservoirs of the disease because the risk of contracting disease for a given individual is greatly affected by factors at community-level, such as level of immunity or disease in the population, environmental conditions, culture, and general contact patterns among individuals in the same group or cluster (Lawpoolsri et al., 2010; Schlagenhauf & Petersen, 2008; Sturrock et al., 2013). This is because the so-called “asymptomatic” malarial infections have been associated with recurring episodes of symptomatic parasitemia. They are also associated with other conditions such as chronic anemia, maternal and neonatal mortality. Co-infection with invasive bacterial disease, cognitive impairment, and ongoing transmission of the parasite are also known.
“Asymptomatic” malaria infections have consequences that have significant impact on health and society, and it has been proposed that they should be renamed “chronic” malaria infections (Cai, Li, Tuncer, Martcheva, & Lashari, 2017; Chen et al., 2016; Greenwood, 1987; Wangchuk et al., 2019).

Isolation and quarantine: Quarantine has not been recommended for malaria since it is not a communicable disease. However, isolation of the patient is considered, and blood precautions should be practiced. Patients should be under barrier protections like bed-nets of screened windows (Leitch, 1926).

Animal Hosts

The switching of parasitic organisms to novel hosts, thereby causing the emergence of new diseases, is of great concern to human health and the management of wild and domesticated animal populations (Leitch, 1926). Hence, when detected in animal hosts, effective control measures should be instituted even though cross transmission today remains a rare possibility. The emergence of the “fifth malaria” whose agent is *Plasmodium knowlesi* may make more challenging the control of this malaria which is the only zoonosis among the five human malaria pathogens. Fortunately, this fifth malaria has been circumscribed to the Malaysia islandic territory (Fornace et al., 2019; Sato et al., 2019).
**Environment**

Environmental modification: Better engineering and design of dams along with irrigation schemes that allow for alterations in the level and flow of water along with flushing of reservoirs can be used to minimize the availability of habitats to the vector. In addition, irrigation schemes that permit intermittent irrigation of fields, as well as alternation between cycles of irrigated and non-irrigated crops, have proven very successful in controlling Anopheles mosquitoes in rice-growing regions of China, India, and Africa (Mayala et al., 2015; Muturi et al., 2010; Mwangangi et al., 2010).

Environmental manipulation: In specific settings, time-limited changes in local vegetation, shade, and drainage patterns provide an effective way to reduce vector habitats. For example, providing shade over the possible breeding grounds of malaria vectors that prefer sunny locales can help reduce the propagation of vector. Whereas, for vectors that thrive in shadier environs, the elimination of overgrowth, weeds, and aquatic plants may markedly reduce breeding potential and thus vector abundance (Konradsen, van der Hoek, Amerasinghe, Mutero, & Boele, 2004).

**Human settlement siting and management**

Strategically placing new human settlements away from potential malaria-breeding areas helps reduce the transmission as malaria vectors do not travel more than a few kilometers from their breeding grounds. More effectively managed and controlled man-made sites where malarial mosquitoes can easily reproduce like water wells and bore holes help reduce malaria breeding in the proximity of human settlements. Some
vectors are known to prefer taking blood meals from animals instead of, or in addition to, human hosts. Thus, strategically locating animal pens and corrals can help divert vectors from human to animal hosts (zoo prophylaxis) (Konradsen et al., 2004).

Natural predators for larval control

The best-known methods for this kind of control include various species of larvivorous fish and biolarvicides, such as *Bacillus thuringiensis israelensis* and *Bacillus sphaericus*. Oil extracted from seeds of the neem tree, also has been tested with success to function as a biolarvicide (Derua, Kweka, Kisinza, Githeko, & Mosha, 2019; Kahindi et al., 2018; Quiroz-Martínez & Rodríguez-Castro, 2007).

Chemical larvicides, adulticides, and ITNS

When other measures are rendered ineffective or do not prove viable and cost effective, Integrated Vector Management (IVM) makes judicious use of methods of chemical control. It is true that chemical tools remain especially important implements in areas where disease transmission is intense and environmental management strategies prove to be ineffective in reducing vector densities adequately to actually make an impact on disease incidence. Thus, chemical methods, which include, indoor residual sprays and space spraying might have a significant role in the reduction of disease transmission, by shortening or interruption of the lifespan of adult vectors. In the urban scenario, applying chemicals to breeding places (larvicides) greatly helps to keep vector populations down. Use of ITNs, e.g. protective insecticides impregnated nets and covering beds, living quarters, or water containers, represents an innovation of recent times, thus combining
the synergies of judicious use of chemical methods in tandem with physical barrier approaches (Floore, 2006; Seleena P, 2004).

**Surveillance**

Surveillance is a tool to define control strategies at all levels and includes mosquito surveillance and Epidemiological surveillance.

Mosquito Surveillance: Larval surveys: Worldwide, for larval surveys, the basic sampling unit is the house or yard. This parameter is systematically searched for water holding containers. Examination of containers is conducted for the presence of mosquito larvae and pupae. Depending on what the objective of the survey is, the search is terminated as soon as larvae are found, or it may be continued until the examination of all containers is completed.

Table 1. Larvae of pupae surveillance methods for vector control.

<table>
<thead>
<tr>
<th>No.</th>
<th>Type of Index</th>
<th>Significance</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>i</td>
<td>House index (HI)</td>
<td>Percentage of houses Infected with larvae and/or pupae</td>
<td>$HI = \frac{\text{Number of Houses infected}}{\text{Number of Houses inspected}} \times 100$</td>
</tr>
<tr>
<td>ii</td>
<td>Container Index (CI)</td>
<td>Percentage of water holding containers infected with larvae or pupae</td>
<td>$CI = \frac{\text{Number of positive containers}}{\text{Number of containers inspected}} \times 100$</td>
</tr>
<tr>
<td>iii</td>
<td>Breteau Index (BI)</td>
<td>Number of positive containers per 100 houses inspected</td>
<td>$BI = \frac{\text{Number of positive containers}}{\text{Number of houses inspected}} \times 100$</td>
</tr>
<tr>
<td>iv</td>
<td>Pupae Index (PI)</td>
<td>Number of pupae per 100 houses</td>
<td>$PI = \frac{\text{Number of pupae}}{\text{Number of houses inspected}} \times 100$</td>
</tr>
</tbody>
</table>

Source: Extracted and adapted from Pan American Health Organization indicators.
Adult Surveys

The collection of specimens for laboratory examination is necessary to confirm the species. Four indices that are commonly used to monitor are described in Table 1.

Landing/biting collection: World Health Organization (WHO) along with other organization like RTI International, United States Agency for International Development (USAID) and United States Centers for Disease Control and Prevention (CDC) have established general guidelines for adult mosquito surveillance (USAID/RTI/WHO, 2012). Landing/biting collection of humans is a sensitive means of detecting low level infestations, but it is very labor intensive. Because adult males have low dispersal rates, their presence can be a reliable indicator of clear proximity to hidden larvae habitats. This is commonly expressed in terms of landing/biting counts per man hour.

Resting collection: In periods of inactivity, it is typical of adult mosquitoes to rest indoors, especially in bedrooms and predominantly dark places, such as cloth closets and other sheltered sites. It is required for resting collection to systematically search these sites for adult mosquitoes with the help of flashlight. Then, as per a standardized timed collection routine protocol in selected rooms of each house, densities are recorded in terms of the number of adults per house or number of adults per man hour of human efforts.

Oviposition traps: The devices used to detect the presence where the population density is low and larval surveys are largely unproductive (when the Breteau index is less than 5) as well as normal conditions are called ovitraps. The surveillance in urban areas
to evaluate the impact of adulticidal space spraying on adult female population is done using the ovitrap (Sivagnaname & Gunasekaran, 2012).

Epidemiological surveillance: The disease epidemiology is complex, since its incidence and prevalence not only depend on the vector behaviors, characteristics of the *Plasmodium* spp. but also on the immune profile of the human host. Therefore, malaria epidemiology is influenced by the environment, the agent, the vector and health care and interventions. (Institute of Medicine Committee for the Study on Malaria & Control, 1991).

In all surveillance centers, the epidemiological surveillance, forecasting and prevention of malaria includes: 1. Epidemiological Information Systems which include a) Identification of indicators of epidemic risk b) Field investigations and c) Geographical information systems; as well as Risk Detection and Forecasting which include: a) Monitoring of morbidity and mortality b) The spleen rate as an indicator of herd immunity c) Monitoring entomological variables d) Monitoring meteorological variables e) Monitoring socioeconomic variable f) Comprehensive monitoring of epidemic risk g) Emergency Preparedness and Epidemic Prevention (Ministry of Health Eritrea, 2003).

**Secondary Prevention and Control**

Global epidemiological surveillance defines secondary prevention is the means that aims to reduce the prevalence of a particular disease by early detection, shortening its duration and use of chemotherapy. Secondary prevention involves controlling and reducing individual risks by using the full range of personal protection and behavior modification measures. These measures are divided into a four-level pyramid of prevention often known as the “A-B-C-D strategy”.
A for awareness and education of the risk of malaria, it requires: a relationship between patient and physician; understanding of prevention strategies; and awareness pre-travel, during travel and post travel.

B for bites: use of personal protection measures requires: an understanding of *Anopheles* behavior, i.e. feeding habits and resting times; use of appropriate clothing, e.g. long-sleeved shirts, long pants, socks and shoes; use of suitable insect repellents, especially around twilight and on the neck, face and ankles; use of clothes and bed nets treated with permethrin; and conditioning of the room for sleeping.

C for compliance with chemoprophylaxis.

D for prompt diagnosis of malaria and securing early treatment. (WHO, 2016)

**Tertiary Prevention Control**

The objective in this level of prevention and control is to avoid incapacities and deaths. Medical treatment to prevent the worst outcomes of a disease in an individual is known as tertiary prevention. Although this may vastly improve the quality of life for the patient, it has at most a limited impact on the spread of the disease. In case of malaria, the drugs used for primary prevention of malaria are also used as a treatment for this disease (Atovaquone/Proguanil (Malarone), Chloroquine, Doxycycline, Mefloquine (Lariam), and Primaquine). This is a form of tertiary prevention. Most of the severe cases of malaria and/or cases that result in death are among children. These children usually suffer from cerebral malaria, severe anemia, and pulmonary disease as a result of the malaria. Unfortunately, Chloroquine is unable to kill *P. falciparum*, as it is now resistant to this medication, except for areas of Central American west of the Panama Canal and Hispaniola. Hence, tertiary care involves the selection, implementation and completion of
the appropriate chemoprophylaxis in all identified case, especially in the case of pediatric, geriatric, pregnant and immunocompromised groups (IPIECA, 2006; WHO, 2016).

**Integrated vector management**

Integrated vector management (IVM) is the strategic approach to vector control promoted by WHO (Navia et al., 2006; WHO, 2017) and it include the vector control. This approach which defined as “a rational decision-making process for the optimal use of resources for vector control”, includes five key elements in its management. These are described in the following paragraphs and illustrated in the accompanying figures.

*Advocacy social mobilization and legislation:* the promotion of these principles in development policies of all relevant agencies, organizations and civil society; the establishment or strengthening of regulatory and legislative controls for public health; and the empowerment of communities.

*Collaboration within the health sector and with other sectors:* the consideration of all options for collaboration within and between public and private sectors; planning and decision-making delegated to the lowest possible administrative level; and strengthening communication among policy-makers, managers of programs for the control of vector-borne diseases and other key partners.

*Integrated approach to disease control:* ensuring the rational use of available resources through the application of a multi-disease control approach; integration of non-chemical and chemical vector control methods; and integration with other disease control measures.
Evidence-based decision-making: adaptation of strategies and interventions to local vector ecology, epidemiology and resources, guided by operational research and subject to routine monitoring and evaluation.

Capacity-building: the development of essential infrastructure, financial resources and adequate human resources at national and local levels to manage Integrated Vector Management, based on a situation analysis (WHO, 2017).

In summary, there have been successful histories of elimination of malaria in different countries from different regions of the world which has allowed the international community to retake the plan for eradication of malaria in the world. Integrated Vector Management is still the most accepted strategy in which education, elimination of mosquito breeding sites, impregnated bed nets (IBNs), surveillance, early diagnosis and early treatment have been the main tools used in an integrated management. However, new treats have emerged which may make in peril this global plan. Among those treats, antimalarial drugs resistance and insecticides resistance are reported as the main challenges. But new technologies like satellite imagine surveillance and the development of new combined therapies and new insecticides may be new and powerful tools to fight the disease.
Figure 7. Integrated vector control approach for mosquito

Source: Annals of Community Health, 2019
Medical Center with Diagnostic Laboratory
Department of Malaria Diagnosis & Control

Sample Screening  Team Approach

Figure 8. Pictorial example of approach to malaria control and prevention

Source: Dr Ricardo Izurieta, University of South Florida, Department of Global Health
Chapter Five: Objectives and Hypotheses

Study Goal

The over goal of this study is to define the main factors determining the decreasing trend of malaria incidence and prevalence in El Salvador for the period 1995 to 2017 and to propose control measures to prevent the reintroduction of the parasite into the country.

Specific Objectives

The research objectives for this study are to:

- Describe the registered cases of malaria in terms of frequency in El Salvador´s 14 departments, grouped by decades from 1994 until 2013.
- Describe the behavior of malaria metric indicators during the analyzed period.
- Describe the trend in malaria cases according to the type of parasite involved in the disease´s etiology.
- Conduct an epidemiological analysis of the decreasing trend of malaria incidence and prevalence in El Salvador between 1955 and 2017.
- Conduct a historical analysis of the malaria elimination in El Salvador for the period 1955 to 2017.
Hypotheses

- Voluntary Collaborators (CV) were the main factor determining a dramatic decrease of malaria incidence and prevalence in El Salvador by autosustainable, decentralized, and timeless diagnosis and treatment.

- The use of Primaquine was another critical factor that eliminated human reservoirs because of its hypnozoiticidal action as well as interrupted transmission because of its gametocytocidal action.
Chapter Six: Materials and Methods

Study Site

El Salvador is located on the Central American isthmus on the Pacific coast bound by Guatemala and Honduras. With a total area of 8,124 square miles, El Salvador is the smallest but most densely populated country of Central America. With a predominantly tropical climate, it has volcanoes, lakes, rivers, mountains and coastal plains in its topography. The population of El Salvador is mostly mestizoid (of European and Native American ancestry). The 2019 census shows the population of El Salvador to be 6.45 million with 46.85% males and 53.15% females with a density of 306.71 per square km.

Table 2. Age structure of El Salvador 2017 estimates

<table>
<thead>
<tr>
<th>Age group in years</th>
<th>Total %</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-14</td>
<td>25.92</td>
<td>820,255</td>
<td>779,306</td>
</tr>
<tr>
<td>15-24</td>
<td>20.23</td>
<td>628,535</td>
<td>620,230</td>
</tr>
<tr>
<td>25-54</td>
<td>39.23</td>
<td>1,120,705</td>
<td>1,300,771</td>
</tr>
<tr>
<td>55-64</td>
<td>7.14</td>
<td>194,360</td>
<td>246,164</td>
</tr>
<tr>
<td>65 and over</td>
<td>7.48</td>
<td>203,320</td>
<td>258,365</td>
</tr>
</tbody>
</table>

With 93% employment rate, the predominant occupation in El Salvador is services (85%) followed by agriculture (21%) and industry (20%).

**Study Design**

The present study makes a retrospective analysis of the information from the Ministry of Public Health and Social Wellbeing (MSPAS) surveillance system. It also carries out a historical analysis of the El Salvador Malaria Control Program since its origin in the 1950s as the El Salvador Malaria Eradication Program. It uses the information available at the MSPAS malaria surveillance system, and it also analyzes documents from international organizations like Pan American Health Organization (PAHO), World Health Organization (WHO), and United Nations UN.

Time-wise the study is defined as a retrospective and linear and systematic revision of the malaria cases is made according to the absolute number recorded yearly, from 1993 to 2013, in relation to the results given by malaria indicator metrics (IPA, ILP, IAES) and the type of parasite related to the disease.

Therefore, the results will encompass two sections: 1. A retrospective analysis of the information retrieved from the El Salvador Ministry of Public Health and Social Wellbeing (MSPAS) Surveillance System and 2. A historical analysis of the El Salvador Malaria Control Program since its origin in the 1950s as the El Salvador Malaria Eradication Program.
**Procedures**

Data pertaining to incidence of malaria in El Salvador was collected for this research project conducted by the University of South Florida, College of Public Health, Department of Global Health in collaboration with the Ministry of Health (El Salvador) and the Pan American Health Organization in El Salvador (PAHO). The principal investigator of this study personally worked with the MSPAS and PAHO officers as PAHO Fellow during the period August 12, 2013 to October 4, 2013 (APPENDIX E) and later as PAHO Fellow from January 16, 2017 to June, 2017 (APPENDIX F). The principal investigator requested officially requested access to the malaria surveillance data and was granted access to all data from El Salvador Malaria Surveillance System (APPENDIX C and D). Primary sources are comprised by the analysis of official documents from the Ministry of Health and Social Wellbeing of El Salvador (MSPAS) and the Pan American Health Organization Mission in El Salvador (PAHO). In addition, the databases at the National Epidemiology Surveillance System of the MOHS were extracted and analyzed as secondary sources specialized key malaria national and international experts were consulted about the subject.
Chapter Seven: Results
A retrospective analysis of the information retrieved from the El Salvador Ministry of Public Health and Social Wellbeing (MSPAS) Surveillance System.

As we can see in this Graphic 9, the malaria program started in the 1950s and the main pick of malaria cases was observed in year 1980 when the Civil War started in the country and then it has been observed a sustained decline of the cases with 0 autochthonous cases in 2017, 2018 and just 1 imported case in 2019 so far.

Figure 9. Malaria El Salvador 1960-2017

Source: Ministry of Public Health and Social Wellbeing of El Salvador
The Malaria Surveillance System at the MSPAS El Salvador, overall reports a reduction in positive cases over the years (APPENDIX G). Although, its neighbor countries Guatemala and Honduras maintain high malaria prevalence in the region, El Salvador has entered in a phase of elimination with 0 malaria autochthonous cases reported in 2017 and 2018 (WHO, 2019). The country has been also ahead of the other Central American countries in terms of the control of malaria mortality since the last malaria death was reported in 1984 and the last case of *P. falciparum* was registered in 1995 (Schneider, 2016). Consequently, for more than two decades only *P. vivax* has circulated in the Salvadorian territory. In addition, the country has maintained a sustained report of less than 50 cases per year for more than one decade since 2006. This achievement cannot be mainly attributed to socioeconomic improvements, climatic
Overall during the period 1994 - 2013, 18857 positive cases were reported of which 10,866 were Males and 7991 were Females (Figure 11). The Malaria Surveillance System from the MSPAS El Salvador reported the maximum number of cases during the year 1996, with 5,888 cases, of which 3,418 were males and 2,479 were females. This can be interpreted as an occupational exposure since men from the no malaria endemic areas in the highlands are seasonal emigrants to the coastal lowlands during the sowings and harvests. A substantial decrease in the number of cases was reported during the year

Figure 11. Malaria cases per year by gender
Source: Department of malaria, Ministry of Public Health and Social Assistance, El Salvador
2013 with 7 cases of which 5 were males and 2 were females. In the next graphic we will observe the initiation of the malaria elimination in El Salvador territories with 0 autochthonous cases reported.

![Malaria El Salvador 2014-2017](image)

**Figure 12.** Imported and autochthonous malaria cases reported in El Salvador 2014-2017

*Source: Department of malaria, Ministry of Public Health and Social Assistance, El Salvador*

During the period 2014-2017, as we can see, El Salvador reported 22 autochthonous cases and 13 imported cases of malaria. All malaria cases were caused by *Plasmodium vivax*. In 2017, El Salvador achieved the goal of 0 autochthonous cases with 4 imported cases. According to recent information provided by a MSPAS health officer, El Salvador also reported 0 autochthonous cases in year 2018. Therefore, if El Salvador keeps reporting 0 autochthonous cases for 2019, in 2020 it can declare the elimination of malaria from its territory. The main focus of the current malaria control
activities is surveillance in the borders, airplane and marine ports.

![Distribution of positive cases under different age groups during the period 1994-2013](image)

**Figure 13.** Distribution of positive cases under different age groups during the period 1994-2013

Source: Department of malaria, Ministry of Public Health and Social Assistance, El Salvador

During the period 1994-2013, the overall the ratio of female to male positive cases is 1: 1.3, in general there is 30% more positive cases in males than female. It is evident that males are more prone to the disease than females, as mentioned, because of occupational exposure while working in the agroindustry such as cotton or rice plantations. We can also observe that overall more positive cases are found in the age group of 15 - 44 for both male and female. In addition, the overall zero positive cases are reported in the age group under 1 year. This age-group information confirms occupational exposure in agriculture plantations as risk factor for malaria.
During the period 1994-2013, a total of 18061 cases of malaria were reported from all the departments of the country. The higher number of malaria cases were reported in Sonsonate department in 1996 - 1264 cases. However, there is an overall decrease in the cases of malaria throughout the departments over the years. From 2000 onwards there is drastic reduction of malaria cases throughout the departments. This department has fertile and well irrigated coastal lands. Its volcanic soils have allowed exuberant agricultural production since the Spaniard conquest. Historically, these lands have produced cacao, coffee, sugar cane, coconuts, fruits, tobacco, tulle, and orchard plants. This department has also been the place where cotton plantations settle. During
the boom of the cotton plantations 1970s-1980s, the place attracted many seasonal internal immigrants that were looking for job at the plantations.

![Department wise cases of Malaria reported over a period](image)

Figure 15. Department wise cases of malaria reported over the period

Source: Department of malaria, Ministry of Public Health and Social Assistance, El Salvador

The Department of Sonsonate which is located in the western El Salvador and close to the Guatemala border, has the highest homicide rate in the country. This high murder rate can be originated by the presence of gangs and coca cartels who have converted this department in part of the of the strategic drug route to Guatemala. Sonsonate city has a key location in the drug trafficking route called in “El Caminito” (The little pathway) which stretches the Honduras border to the Guatemala border (Grandmaison, 2011).
In Figure 15, we can observe that overall, Sonsonate department reports the maximum number of malaria cases, followed by La Union and Ahuachapan. The department that is least prone to malaria is Cabanas with 41 cases over the period.

![Epidemiological Risk Stratification of malaria, 1978-2009](image)

<table>
<thead>
<tr>
<th>Endemic Area</th>
<th>Altitude Above Sea Level</th>
<th>KM²</th>
<th>Population</th>
<th>Voluntary Collaborators</th>
<th>Health Centers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hyperendemic (High Risk)</td>
<td>0-300</td>
<td>4,819</td>
<td>1,880,630</td>
<td>1,654</td>
<td>131</td>
</tr>
<tr>
<td>Mesoendemic (Moderate Risk)</td>
<td>300-600</td>
<td>3,216</td>
<td>1,370,924</td>
<td>756</td>
<td>81</td>
</tr>
<tr>
<td>Hypoendemic (Low Risk)</td>
<td>600-900</td>
<td>11,118</td>
<td>2,490,630</td>
<td>365</td>
<td>93</td>
</tr>
<tr>
<td>Non Malarial</td>
<td>900 and above</td>
<td>1,881</td>
<td>1,103,021</td>
<td>267</td>
<td>71</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>21,034</strong></td>
<td><strong>6,458,234</strong></td>
<td><strong>3,092</strong></td>
<td><strong>376</strong></td>
</tr>
</tbody>
</table>

Source: Vector Surveillance and Control Unit MSPAS, May 2009

In Figure 16, we can see the hyperendemic, mesoendemic and hypoendemic areas.
Microanalysis of data from 2001 to 2007 to evaluate the efficacy of local machinery in malaria control. Malaria cases detected by VCs.

Figure 17. Overall scenario of P. vivax for the period 2001-2007

Source: Department of malaria, Ministry of Public Health and Social Assistance, El Salvador

The identification of malaria was facilitated predominantly by Voluntary Collaborator in 2001.

The overall examination of slides was facilitated by the medical services from 2001 to 2007, with Voluntary collaborators accounting for a close second much above the figures of active search and special survey. Over 2002 to 2007, this role was taken over by the Medical service, but the Voluntary Collaborator still remained a close second in identification of P. vivax activity.

The Voluntary Collaborator was the predominant malaria Identification machine in 4 departments followed closely by the Medical Services and this trend was reversed over the other departments. The Active search and Special survey seem to have played a very small role in the process P. vivax.
Microanalysis of data from 2001 to 2007 to evaluate the efficacy of local machinery in malaria control. Slides read by VCs

![Graph showing overall scenario of slides examined during period 2001 -2007](image1)

Figure 18. Overall scenario of slides examined during period 2001 -2007
Source: Department of malaria, Ministry of Public Health and Social Assistance, El Salvador

Microanalysis of data from 2001 to 2007 to evaluate the efficacy of local machinery in malaria control. Malaria cases detected by VCs by Department

![Graph showing department wise overall scenario of P. vivax for the period 2001 -2007](image2)

Figure 19. Department wise overall scenario of P. vivax for the period 2001 -2007
Source: Department of malaria, Ministry of Public Health and Social Assistance, El Salvador
In Figure 20 we can see that in hyperendemic areas, most of the malaria workforce were VCs. In the country there were 3,022 (82%), 369 (10%) Health Workers and 292 (8%) Malaria MSPAS Personnel. These confirms the malaria work was mainly carried out by the VCs.

The Sonsonate department, the department with the highest malaria prevalence in year 2013, has fertile and well irrigated coastal lands. Its volcanic soils have allowed exuberant agricultural production since the Spaniard conquest. Historically, these lands
have produced cacao, coffee, sugar cane, coconuts, fruits, tobacco, tulle, and orchard plants. This department has also been the place where cotton plantations settle. During the boom of the cotton plantations 1970s-1980s, the place attracted many seasonal internal immigrants that were looking for job at the plantations. The Department of Sonsonate which is located in the western El Salvador and close to the Guatemala border, has the highest homicide rate in the country. This high murder rate can be originated by the presence of gangs and coca cartels who have converted this department in part of the of the strategic drug route to Guatemala. Sonsonate city has a key location in the drug trafficking route called in “El Caminito” (The little pathway) which stretches the Honduras border to Guatemala (Grandmaison, 2011).
Chapter Eight: Results
A historical analysis of the El Salvador Malaria Control Program since its origin in the 1950s as the El Salvador Malaria Eradication Program

El Salvador presents an interesting case study from the epidemiologic perspective of an effort to control and eradicate malaria over the last 7 decades. The various national policy decisions, strategy planning, world outlook, developed nation assistance, political circumstances and climate have all had a role to play in the incidence, effort and subsequent success or failure to control malaria within El Salvador. Chronologically, the incidence of malaria has been proposed to be classified into five predominant time phases:

1955-1969: Global Eradication Campaign
1970- 1980: Resurgence
1981- 1995: Rapid Decline
1996- 2011: Continued Decline
2011 till date: Endgame (11)

1955-1969: Global Eradication Campaign

The decade of 1950s saw the newly established World Health Organization (WHO) initiate the Global Malaria Action Plan (GMAP) which saw several countries around the world along with El Salvador which came up with its own National Malaria Program align with this global initiative. (Schneider K et al., 2016).

Under the aegis of this program, during this time period, the following important
events and actions marked the course of the disease.

*Defining subnational maps of malaria incidence*

Due to the heterogeneity of the distribution of malaria incidence and prevalence, the definition of subnational maps to concentrate the malaria control activities in those states of provinces of high transmission was a successful strategy to use the resources in a more efficient way.

Figure 21. Decrease of malaria cases in El Salvador during the DDT spraying

Source: Babione 1966
As described in one historical document by Covell “At the annual Conference of Medical Research Workers of 1925 the following resolution was passed: The conference is impressed with the great need of a permanent organization for carrying out continuous and adequate investigation in regard to the prevention of malaria in India. It also wishes to call attention to the necessity of adequate provincial malaria organizations working in collaboration with the central organization and considers that the constitution of such organization (which should include at least one effective malaria worker) ought to receive urgent and early attention by -local governments: “Among other guidelines it was required: “To carry out epidemiological investigations mapping of endemicity, study of hyperendemic and healthy areas, study of malaria statistics on modern lines and generally to elucidate the underlying principles of malaria prevalence in India.” (Covell, 1942).

Indoor residual spraying with DDT

Although DDT has been found to persist in the environment without degradation and to cause negative impacts in some animal species, its efficacy for the malaria control was proved during the malaria eradication program in the Americas. For example, in the 1960’s, the programs of Jamaica, British Honduras, and Trinidad, were examples of the rapid and complete disappearance of malaria under residual house-spraying with DDT (Babione, 1966). Actually, the use of DDT by itself was the main tool for the malaria eradication in British Honduras (Babione, 1966). In El Salvador the development of Anopheles resistance to DDT most likely was caused by the intensive use of DDT in the cotton plantations that were introduced in the country previously to the malaria eradication program (Babione, 1966).

Mass prophylaxis

Malaria was successfully controlled by mass administration of antimalarial schizonticidal and gametocytocidal drugs which were administered to all endemic
population of an area every week or every other week (Clyde, 1962).

*Environmental Management Techniques*

The strategy of eliminating mosquito breeding sites was complementary to all other control measurements. The positive impact of controlling mosquito breeding sites was evident; nevertheless, environmental changes, may have cause those *Anopheles* spp. with potential capacity to transmit the parasite but with originally innocuous as a vector transmitter. By altering its feeding habits and therefore (Giglioli, 1963).

*Establishment of Voluntary Collaborator Network (VCN)*

The VC network was stablished as a community-based structure with a strong decentralization and autonomy to strength mainly the second level of prevention with timeliness diagnosis and treatment of malaria cases. The social recognition and pride were key elements in maintaining the VC network even with during the civil war. The pride and social commitment was such that VC trained their sons, daughters, younger brothers and sisters, nephews and nieces

*Set up of United States Center for Disease Control (CDC) in San Salvador*

In the 1960s the United States Centers for Disease Control and Prevention established one of its malaria research stations under the CDC Division of Parasitic Diseases to mainly support the vector and parasitology research. This CDC’s technical support make it possible a better knowledge of the parasite and a control of the disease based on evidences (Keiser, Singer, & Utzinger, 2005; Konradsen et al., 2004; Robert LL, 1991; Sauerbrey, 2008; Schneider K et al., 2016).

**1970- 1980: Resurgence**

The decade between 1970 and 1980 has been termed as the decade of
resurgence of malaria because El Salvador showed an 852% increase in incidence as compared to the previous decade with 95,835 cases (Schneider K et al., 2016). The important features of this decade were as follows:

*Cotton belt revolution*

In the 1970s there was an expansion of the cotton plantations in El Salvador with a peak production in 1978. The expansion of the cotton plantations could have contributed to the increase of malaria incidence by determining migration of agriculture workers to coastal malaria endemic areas. The migration of populations of no endemic highland regions to endemic coastal areas with high transmission of the disease. (Chevez, 2019; Schneider K et al., 2016). But also it is plausible that the intense use of pesticides in these cotton plantations could have contributed to the development of insecticide resistance in the *Anopheline* species (Anderson, 2009).

*Replacement of DDT with Ortho-isopropoxyphenyl methylcarbamat (OMS-33) spraying*

The impacts of DDT in the environment, humans and animals, especially on one of the United States symbols, the Bald Eagle (Grier, 1982), determined the withdrawal of DDT as insecticide in all the world. Of course, DDT was not only banned in agricultural practices but also on the control of vectors of human disease (Quiroz-Martínez & Rodríguez-Castro, 2007; Schneider K et al., 2016).

*Launch of National Malaria Program incorporating stratification, lab decentralization and multiplication and adoption of 5 day Primaquin regimen*

In 1979, with the support of the United States Centers for Disease Control and Prevention, the country was stratified in hyper-endemic, meso-endemic, and hypoendemic based on the prevalence, incidence and altitude over the sea level. This stratification allowed El Salvador to use more efficiently its human and financial resources.
Therefore, VC as well financial resources and control activities were concentrated in those areas of high transmission with a more rational distribution of resources. Also, the malaria treatment was standardized with a 5-day Chloroquine/Primaquine regimen (Burton et al., 2018; WHO, 2017). As recently described by Reina-Ortiz et al, primaquine is not only a hypnozoiticidal drug but also an gametocytocidal drug with tremendous contribution to the elimination of human reservoirs and interruption transmission from human to vector (Engleberg N, 213; Reina-Ortiz, 2015).

Funds from The United States Agency for International Development (USAID)

The malaria control program was mainly funded by government resources and additional support of the United States Agency for International Aid (USAID). The USAID resources were mainly invested in the strength of the national malaria surveillance system. When the CDC station was moved from El Salvador to Guatemala a lot of the technical and financial assistance was lost (Frederick et al., 2016; Schneider K et al., 2016).

1981- 1995: Rapid Decline

The time period was characterized by some of the most interesting salient features that challenge conventional epidemiological wisdom. These were:

Civil war from 1980 to 1992

El Salvador went into a civil war that caused about 70,000 deaths and 2 billion US dollars in financial damages. Despite the calamitous conditions, malaria cases continued to dramatically decrease mainly due to the strong grassroots of the malaria VC network which continued operating. At the beginning of the civil war in 1980 it was reported more
than 95,000 malaria cases and by the end it was reported less than 3,000 cases with an approximate 95% reduction (Schneider K et al., 2016).

**Collapse of cotton industry**

The civil war also had its impact in the cotton plantations with the closure of their operations in the country as well as the immigration of workers due to the loose of their employments. Nevertheless, similar collapse of this agroindustry was observed in neighborhood countries such as Guatemala (Schneider K et al., 2016).

**Transition of National Malaria Program**

A transition to incorporate risk stratification, integrated control approach, dynamic epidemiology: One of the contributions of USAID international collaboration in the fight against malaria it was the stratification of El Salvador zones into hyper-endemic, meso-endemic, and hypoendemic. This stratification allowed the redistribution of human and financial resources to better serve areas of high prevalence sans incidences (Burton et al., 2018; Cohen JM et al., 2012; Ministry of Health Eritrea, 2003; P. A. H. O. PAHO, 2004; Sivagnaname & Gunasekaran, 2012).

**Environmental modification**

The environmental control measurements included the elimination of breeding sites which allowed the restriction in the use of insecticides and preventing the development of vector resistance. Hundreds of drainage canals were constructed to discharge stagnant waters into rivers and estuaries. (Quiroz- Martínez & Rodríguez-Castro, 2007; Schneider K et al., 2016)

**Aggressive case detection**

Cases were detected either by the VC which participated in passive and active
case detection, health personnel (physicians, nurses, specialists, etc) that usually participated in a passive case detection and in active case detection during the annual or semester surveys. The national malaria surveys were a key activity in which the few cases that were not detected during that year by the VC- were diagnosed by house by house “epidemiological combing” activities (Schneider K et al., 2016). The preponderant influence of the VC in the dramatic decline of malaria during this period is evidenced (IPIECA, 2006). As mentioned, the active case detection was carried out during the national surveys with visits to homes, collection of blood smears, diagnosis and antimalarial treatment administration. These national surveys were applied in proppositive national samples. In 1989, VC were responsible for 70.4 percent of all blood samples taken and 94.4 percent of all cases diagnosed (Table 3). The VC also participated along with the government health care personnel during national surveys and 29.5 percent of all blood samples taken during active detection campaigns (Schneider K et al., 2016).

**Sustainable domestic funding**

USAID financial support was crucial to initiate the malaria control activities in all Central American countries; however, reductions in the external financial support and the decline of incidence in the region caused a constrain in the resources available for the control programs. El Salvador program was an exception since the VC network was already consolidated and its financial dependence from the El Salvador Ministry of Public Health and Social Wellbeing was maintained at a relatively very low cost (Schneider K et al., 2016).
1996- 2011: Continued Decline

The trend of falling numbers in incidence of malaria in El Salvador continued in the end of the last millennium into the new one over a period of 13 years. This continuing downfall was supposed to be an extension from the previous decade. However, this time period was not a static one but saw various characteristic features like:

Table 3. Malaria case detection by VC and other health personnel EPI weeks 1-39,1993

<table>
<thead>
<tr>
<th>Department</th>
<th>VC/ Health Personnel</th>
<th>Hyperendemic</th>
<th>Mesoendemic</th>
<th>Hypoendemic</th>
<th>Nonmalarial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Santa Ana</td>
<td>Voluntary Collaborator</td>
<td>35</td>
<td>531</td>
<td>53</td>
<td>666</td>
</tr>
<tr>
<td></td>
<td>Med/Specialist</td>
<td>2</td>
<td>136</td>
<td>5</td>
<td>226</td>
</tr>
<tr>
<td>Ahuachapan</td>
<td>Voluntary Collaborator</td>
<td>332</td>
<td>3450</td>
<td>41</td>
<td>975</td>
</tr>
<tr>
<td></td>
<td>Med/Specialist</td>
<td>31</td>
<td>600</td>
<td>0</td>
<td>123</td>
</tr>
<tr>
<td>Sonsonate</td>
<td>Voluntary Collaborator</td>
<td>472</td>
<td>5838</td>
<td>10</td>
<td>284</td>
</tr>
<tr>
<td></td>
<td>Med/Specialist</td>
<td>1</td>
<td>100</td>
<td>1</td>
<td>19</td>
</tr>
</tbody>
</table>

Source: Department of malaria, Ministry of Public Health and Social Assistance, El Salvador

Integration of National Malaria Program (NMP) into National vector borne disease control programme (NVBDCP) and decentralization of the Ministry of Public Health and Social Wellbeing (MSPAS) system

During this process of integration- decentralization, the malaria control program was integrated into the epidemiological control activities of the MSPAS, specifically into the Unit of Vector-borne Diseases Control at the Department of Environmental Health (Dr Aleman personal communication). However, at the same time, the MSPAS went into a process of decentralization of its operations by giving more administrative autonomy to territorial Departments and Health Care Geographic Areas denominated Sistema Basico de Salud Integral (SIBASI) (Schneider K et al., 2016).
**Consistent national funding**

The reestablishment of peace after the Civil War in El Salvador allowed the providing of a moderate but consistent financial support of the vector-borne diseases control including malaria. Although El Salvador experienced a reemergence of dengue and the emergence of dengue hemorrhagic cases, due to the decentralization process and the strong grassroots of the VC network (Dr Izurieta personal communication), the malaria control program was very active specially in those areas of high risk (Hoffman S, 2011; Schneider K et al., 2016).

**Introduction of border surveillance**

El Salvador has been a pioneer in malaria border surveillance. The MSPAS implemented a surveillance system in all points of entry like border crossings, airports, and marine ports. In these populations the application of chemoprophylaxis was one of the control activities. In this thesis it is proposed the implementation of a malaria passport similar to the yellow fever certificate (Jacobson et al., 2017).

**Continuing evidence-based risk stratification**

The stratification in hypo-endemic, meso-endemic, and hyper-endemic malaria areas in the country continued during this period. This strategy allowed to concentrate the VC in areas of transmission. In addition, Long Lasting Insecticide Bed Nets (LLINs) and bed-nets were just distributed in hyperendemic areas (IPIECA, 2006; Schneider K et al., 2016).

**Continuing use of 5-day regimen**

In this period the combination Chloroquine + Primaquine continued as the standard malaria treatment. It is important to emphasize that Primaquine not only eliminates human chronic
reservoirs by killing hypnozoites but also stops transmission by killing gametocytes (Schneider K et al., 2016).

**2012- 2017: Endgame**

As the current scenario stands, El Salvador is poised to step into the phase of elimination of malaria from its shores. This phase has been the culmination of the long history of planning and execution over the last 70 years. It features:

*Transition of Vector Control Program (VCP) to National Malaria Strategic Plan (NMSP) 2011 to 2014*

This strategy proposes an Integrated Vector management (IVM) to achieve the greatest disease-control benefit in the most cost-effective manner. Therefore, all vector control activities are integrated into the NMSP of the MSPAS.

*Continued stratification*

The stratification strategy continues in El Salvador and it is considered a critical tool to prioritize control interventions in places where a malaria case has been imported or an autochthonous case is reported. Areas where active screening is done include those places where the vector exists, disadvantaged socioeconomic populations and immigrants (IPIECA, 2006).

*Pinpoint targeted vector control*

In this period the vector control activities have decreased and are concentrated in those areas where foci are detected. Also, Ultra Low Volume (ULV) spraying has been introduced and larvae control measurements have continued just in foci which are analyzed using Geographic Information Systems (GIS) and Remote Sensing (RS) (Chevez, 2019; Ricklefs & Fallon, 2002).
**Shift back from 5-day regimen to 14-day regimen**

In 2013, El Salvador integrates in its malaria control program the use of 3 days of Chloroquine + 14 days of Primaquine, following the global recommendations for malaria control. It is also important to mention that currently CVW only carry out diagnosis, surveillance and reference of malaria cases to the MSPAS health care units where patients receive treatment (Schneider K et al., 2016).

**Maintenance of surveillance**

Due to the heterogeneity of the disease distribution in endemic countries, the use of high-resolution maps using satellite images has substantially increase the efficiency of control programs by targeting only those areas at high risk and/or high burden (Weiss et al., 2019). Therefore, it is proposed in this analysis the use of “hot spots” to define areas of local transmission as well as border areas of high risk for the reintroduction of the parasite.

**Maintenance of finance**

For the contrary to other Central American countries, El Salvador has become financially auto-sustainable since most of the resources are local. This conditions allow a permanent and stable program for the control of the disease (Ricklefs & Fallon, 2002).

**Salvador’s approach to address malaria**

As a summary the malaria eradication phase of demonstrated that DDT used as a residual indoor spray was extremely effective in controlling the transmission of malaria in most of the areas where it has been properly applied and it was not used in agriculture. The most serious obstacle to its success has been the development of resistance of Anopheles spp. mosquitoes mainly due to its intensive use in agriculture. The introduction
of Primaquine in the combine Chloroquine + primaquine therapy has become a key element for the elimination of chronic human reservoirs because of its hypnozoiticide action, as well as for the stopping of malaria transmission because of its gametocytocidal action. But the main element that has brought the country into an elimination phase is the VC that carried out a decentralized and auto-sustainable control activities even during the civil war.
Chapter Nine: Discussion

Malaria still remains a serious parasitic disease in the developing world resulting in high morbidity and mortality. Although the areas where transmission takes place have reduced over time, and they are by now confined to the inter tropical areas, the number of people living at risk has grown to about 3 billion, and it is expected to go on increasing. It is reported that there are over 500 million cases every year, and between 1 and 3 million deaths. The disease also carries a huge burden that impairs the economic and social development of large parts of the planet (Navia et al., 2006; WHO, 2018).

The success story of the Central American Nation of El Salvador has proven itself to be a study model for the region and the world in the mission to eradicate malaria. The impressive decrease of malaria incidence from 2,767 cases in 1994 to 7 cases in 2013 (Table 1) and 0 autochthonous cases and 3 imported cases in 2017 evidences this statement. (WHO, 2018). It was with this aim of analyzing the success and critical evaluation of the malaria control in El Salvador that the malaria data spanning two decades from 1994 to 2013 was studied as a part of this document.

To an untrained eye, the success of El Salvador in controlling malaria within its boundaries might appear a series of fortunate coincidences leading to an ideal culmination of target achievement. However, to an epidemiologist, this country presents a case study in how well directed efforts, smart policy decisions, international
collaboration and grass root participation can enable a nation to overcome a disease against all geographical, political and economic odds stacked against it.

Even though this document studies the disease of malaria from 1994 to 2013, it is judicious to include salient features of El Salvador´s fight against malaria- as mentioned the work of the VC and the use of Primaquine as hypnozoiticide and gametocytocide since its inception in the 1950s. This is because, several factors from that period have had a long-lasting effect that helped the country reap benefits well into the new millennium.

One of the most significant policy decisions that have benefitted El Salvador over these 7 decades was the division of the country into 14 geographical departments (Chevez, 2019). In the initial phase, it allowed identification of high incidence areas and enabled focusing disease control measures towards the high incidence areas. In the very early stages, this strategy enabled elimination of malaria from the high altitude regions and then enabled concentration of disease control measures in the cotton belt (Anderson, 2009). In the later stages, this division into departments helped monitoring, surveillance and effort concentration which proved to be very effective over time and still does.

Another significant positive step taken by El Salvador was to align itself with the global effort to control malaria from its inception (Ricklefs & Fallon, 2002). The biggest benefit of this alignment was inclusion of the country in the Global road map of controlling and eliminating malaria. This time period also coincided with the industrialization of the country and development of the cotton belt which gave an impetus to migration close marshy areas where the plantations were located. The global knowhow of vector control was implemented and helped keep the disease in control in spite of the identification of this region as “malarial” (Karlen, 1996; Ricklefs & Fallon, 2002).

Along with the aforementioned factors, the geographical proximity and keen involvement of a developed nation like USA to El Salvador went a long way in supporting the effort to control and eliminate malaria from the shores of the country. The
establishment of the CDC Center in El Salvador, the consistent USAID funding that was awarded all went a long way in bolstering the fight against malaria. This financial support from the United States of America continued for two decades but what was commendable on the part of El Salvador was the fact that even when financial support from the US and the Global bodies dwindled, the Government kept consistently financing the drive against malaria. So we observe that even with collapse of industry, climatic pressures and the civil war, the financial will in the control and elimination of malaria never lost steam in El Salvador till date (Chevez, 2019; USAID, 2019).

But, the most prominent role players that emerges from the immensely successful endeavor to control and eliminate malaria in El Salvador, surprisingly is the Voluntary Collaborator. Established as a component of the malaria control machinery since the earliest days (1950s), this Voluntary Collaborator, without any medical qualification and with minimal specialized training proves to be one of the most important and successful means of case identification, record keeping, control and even treatment of malaria throughout the nation. Several beneficial factors contribute to the successful role that Voluntary Collaborators have played in the fight against malaria in El Salvador. The foremost advantage is that these voluntary collaborators were selected from the local population. Over, the decades, the role of Voluntary Collaborator was in many cases, passed on from the older generation of the family to the next. The Voluntary Collaborators were given the basic knowhow of methods of vector control. They were trained in case identification. Eventually they were given bigger responsibilities like blood sample collection, medical center coordination and even treatment with Antimalarials. The social status associated with this post and the technical knowledge along with control responsibility and treatment power that came with it went a long way in control and elimination of malaria over the decades in El Salvador. The biggest advantage of this was that the network based at grass root levels never failed in natural disasters, climatic pressures or even during the civil war. Vector control measures were easily instituted,
and case identification was more rapid thereby facilitating quick local response. Therefore, the Voluntary Collaborator emerges as one of the masterstrokes that works on several different levels for the success in control and elimination of malaria (Anderson, 2009; Warren, Collins, Skinner, & Larin, 1975).

In the fight against malaria, along with vector control, rapid detection and successful management of positive cases is equally important. This aspect of the disease control has been well tackled in El Salvador over the decades. The country made sure since the initial days to stay abreast with the Global policy of control and eradication of malaria. The establishment of the United States CDC Laboratory in the 1950s followed by establishment of medical centers and laboratories which were then decentralized and multiplied to reach local population went a long way in the country’s ability to identify, manage and control the disease (CDC, 2018; Chevez, 2019).

The adaptation of risk stratification, integrated control approach, dynamic epidemiology and aggressive case detection went a long way in controlling the disease. The country also undertook environmental modification on huge scales to eliminate pro-vector topography (Chevez, 2019). At the same time, global policies of vector control were instituted like use of DDT and the 5-day Primaquine regimen.

However, what defines the success or failure of a program is not the popular decision taken once and persisted with but periodical evaluation and revaluation of these policy decisions with changing times, circumstances, global patterns and local situations. El Salvador has successfully achieved this throughout the last 6 decades as can be evident from changeover from USAID to domestic funding, transition from the US CDC to decentralized laboratories, adoption of 5 day Primaquine regimen and eventual reversion to 14-day chloroquine + Primaquine regimen and the transition from National Malaria Program to National Vector Control Program (Chevez, 2019). At the same time, it is critical to persist with factors that have a proven success record such as the Voluntary
Collaborator. El Salvador did not only persist with the Voluntary Collaborators, but also empowered them over time so as to add to the success already achieved by this entity.

It was due to all these factors that laid the foundation of the malaria program in El Salvador that it could maintain its steady pace towards elimination in spite of two major calamities. In the decade before 1980, there was a huge resurgence of malaria in El Salvador due to losing global initiative. This taught the nation to be self-reliant in its fight against malaria and persist with efforts at grass root level rather than depend on global cues or foreign aid. This stood the nation in good stead when civil war broke out in 1980. This civil war lasted from 1980 to 1992, which by popular belief should have shown further deterioration in the malaria situation. However, it did not. This can be attributed to the collapse of the densely populated cotton belt as well as the nature of malaria program that depended on local voluntary collaborators and national funding rather than centralized medical facilities or foreign aid rendering it immune to the political situation.

In the second instance, and here we approach the time span studied in this document, the spike in malaria cases is seen in the year 1996 at 5888 positive cases. This spike can be attributed to the effects of natural phenomenon like El Nino as well as to global warming. (30) In spite of this fact, El Salvador rallied through this spike in cases of malaria with the help of transition of National Malaria Program to incorporate risk stratification, integrated control approach, dynamic epidemiology, environmental modification, aggressive case detection and domestic funding augmented by USAID (Curtis et al., 2003; Rowland et al., 1999; Seyoum et al., 2012). The resulting effect was that of rapid decline in the incidence of malaria within the subsequent years and approach towards elimination where, in the last year recorded as a part of this document, only 7 cases were reported in 2013 of which, 4 were migrants entering El Salvador.

While studying the overview of the primary numerical values, we should not forget the story related by the smaller numbers and their significance. The studied data shows higher incidence among males as compared to females. The incidence is also higher in
the age groups between 15 to 44. This affirms the fact that the males of the population tend to spend more time outdoors for financial purposes. This also corroborates the fact that the population within the range of 15 to 44 tends to be more active for school, work etc. This goes to show that the more active, mobile component of the population tends to be more susceptible to vector attacks.

The numbers also show that the geographical distribution of the disease is more concentrated towards areas that are marshy, inaccessible and close to the borders. This goes to show that in regions where vector control measures cannot be instituted effectively and areas which are good vector breeding environments present a challenge to malaria control. This is further complicated by situation across the border placing a marginal dependence of a country’s success in controlling malaria on the effectiveness of the same on the part of its immediate neighbors.

If malaria is studied from the perspective of the levels of prevention and control, it emerges that several positive and effective efforts of primary, secondary and tertiary prevention and control implemented by El Salvador.

Since vaccine for malaria is nonexistent till date, the onus of primary prevention of malaria in El Salvador is based on preventing the onset of disease. This is achieved by prevention or minimizing interaction between host and vector. In case of El Salvador, the management of host factors was carried out by means of behavioral change that was facilitated by the Voluntary Collaborators (Rowland et al., 1999) and by insecticide treated mosquito nets (WHO, 2015). Vector control was achieved by elimination of breeding sites: source reduction and insecticides (indoor and outdoor). The elimination of breeding sites was mainly targeted at the irrigation channels in the cotton belt and the marshy areas around reservoirs and water bodies. Outdoor as well as indoor spraying was carried out using DDT which was later replace by OMS-33 when resistance developed (Chevez, 2019). In recent times the mosquito parasite, *Romanomermis culicivorax*, was mass produced for the treatment of *Anopheles albimanus* breeding area in El Salvador as a
means of biological control (Fisher et al., 1999). El Salvador has successfully achieved management of primary management of infected humans by first, adoption of 5 day Primaquine regimen and eventual reversion to 14-day chloroquine + Primaquine regimen and the transition from National Malaria Program to National Vector Control Program (Chevez, 2019). Environmental manipulation two large environmental management projects began in the Department of La Libertad to limit standing water of two estuaries: areas where the mouths of rivers entering the Pacific Ocean would close during the dry season, producing large mosquito breeding sites often close to large towns. The drainage projects included three main components: 1) construction of a central ditch to connect the estuary and the ocean and drain potential breeding sites in the estuary into the ocean during the dry season; 2) construction of a dam in the river to remain closed during the dry season, thus causing a diversion of water directly from the river to the ocean, by passing the estuary and also containing a gate that, when opened, allowed sea water, whose increased salinity served to inhibit larval development, to flow back into the estuary; and 3) development of several canals that drained low-lying areas back into the river during the rainy season. The drainage project was completed on the Ticuiziapa estuary in 1987 and on the San Diego estuary in 1992 (Chevez, 2019). The role of human settlement siting and management was critical in the primary control of malaria in the initial stages because of the presence of the cotton belt and immigration of workers to the plains for work. With the civil war, however, the industrial collapse led to the collapse of the cotton belt where it ceased to be an entity to be considered in control of malaria (Anderson, 2009). Epidemiological surveillance, focused especially at the borders is one of the important components of malaria control for El Salvador (Jacobson et al., 2017).

The secondary prevention of malaria re-emphasizes the role of the Voluntary Collaborator because he is an important administrator and facilitator for awareness and education, propagation of bite prevention techniques, compliance of chemoprophylaxis and prompt diagnosis and treatment. At the same time, the decentralized medical centers
and laboratory network in El Salvador effectually elevates the secondary control of malaria to one of the best globally (Chevez, 2019).

Since tertiary control of malaria is coincident with primary prevention, the effectiveness is carried over in case of El Salvador thereby vastly reducing the mortality and morbidity of the disease.

The data collected in this study also confirms our belief in the local participation in the effective control of malaria. The numbers show that the Voluntary collaborators emerge as the close second most important entity instrumental in detecting and managing malaria cases throughout the country. Moreover, in 4 of the geographical departments, they are the primary detecting and managing entity. This goes to show that the success of the program is based on a sound foundation of geographical division and local participation.
Chapter Ten: Conclusions

From being termed ‘malarial’ at the midpoint of the 20th century to stepping into the elimination phase and being awarded the ‘Malaria Champion Award’ at the beginning of the new millennium, El Salvador has come a long way in its walk on the road to eliminate malaria. All this, in spite of its geographic location in the ‘endemic zone’ of the globe, makes the success story of this Central American nation an interesting study from the epidemiologist point of view. To effectively understand the success achieved by El Salvador in today’s date, the sequence of events over the last six decades must be taken into perspective. Although the data that needs to be evaluated and analyzed has to be modern and within the proximity of the present, it has to be over a satisfactory spectrum, over at least two decades. Within this data, a subset of recent years can be studied for a more accurate analysis of the current situation. Keeping these facts in mind, the malaria data from 1994 to 2013 was studied. Along with this data, a subset data from 2007 to 2013 was also studied. The statistical analysis and evaluation of this data threw up some interesting findings.

The most important fact that emerged from the analyzed data was that, El Salvador had its fair share of malaria cases over the two decades. There was a sudden spike in the year 1996 which can be attributed to extreme climatic events like the El Nino. However, subsequently the incidence showed an acute fall and continuing reduction to almost negligible numbers towards the end of the studied period. This is evidence
corroborating that the policy decisions and strategies that were established right at the beginning of the fight against malaria are still effective in achieving the ideal results.

These include aligning with global will, association with developed nations in the geographic vicinity, domestic funding and strategic planning. El Salvador aligned with the Global will to eradicate malaria right at its inception in the 1950s. It also associated with the United States of America and reaped rich benefits from the CDC center established in the 1950s within its territory. The country also benefitted from the USAID extended by the same neighbor. At the same time, domestic funding was diverted towards the effort and even when global funding and USAID diminished, the domestic funding persisted and even compensated, thereby maintaining the momentum of the malaria control program.

The strategic planning on the part of El Salvador in the long run turned out to be a masterstroke that worked well over decades, through civil war, natural disasters and till present, guiding the country into the final steps of elimination. This involved geographic distribution of the country into 14 departments. This enabled identification of high incidence regions and facilitated concentration of efforts there. At the same time, the efforts mentioned were exerted by the machinery that was created at the grassroots level. This included a functionary termed as the Voluntary Collaborator, an individual chosen from the local population and trained in identification, recording and basic medical management of malaria cases in the vicinity. This, along with the eventual decentralization of the laboratories enabled early identification and effective treatment of malaria which in turn allowed the elimination of reservoirs and the interruption of its transmission for a rapid control even during periods of strife.
Another important aspect of the malaria program of El Salvador was periodic critical evaluation and modification of the program to meet the demands of the disease, the population and the world outlook. This can be evident in shift from DDT to OMS33, or from the 5-day Primaquine regimen to the 14-day regimen. As mentioned, Primaquine is one of the few hypnozoiticide and gametocytocide antimalarial drugs which have two unique control effects: eliminate human reservoirs and stop transmission to mosquitos. This helped El Salvador to stay one step ahead of the disease or if not, at least keep pace with it, which is the key in eliminating it.

The above factors in control of malaria have been so effective that in the final year included in this study more than half the reported cases were migrants from across the national borders. This according to us is an indication that the so called “endgame” in the fight against malaria is going to be as laborious and challenging as the pathway towards controlling it. This, because, today’s day and age has put forth completely new challenges, hitherto not witnessed in cases of diseases that humanity has till date conquered, like smallpox. One example is control of international borders in face of opening of global frontiers, ease of long-distance travel and need of large populations to migrate over these long distances. Thus, the fight against a disease is no more limited within the nations frontier, but it needs strengthening at the borders as well as international and global cooperation to extend it into neighboring regions as well.

Thus, we may conclude that El Salvador is a brilliant example of a success story of fight against malaria that may be considered in its most vital and challenging chapter.
of transition from control to elimination, which, with the right strategy and execution might be a fairy tale ending that frees the country from malaria “ever after!”.
Chapter Eleven: Recommendations

The study of El Salvador's success in control of malaria and its entry into the elimination phase can facilitate drawing up several recommendations for the rest of the region and the world to incorporate in their programs to control and eliminate malaria. El Salvador has proved the world that “Malaria Can Be Defeated”. The main artifices of this successful history have been the Voluntary Collaborator (VC) which community grassroots work is critical for any disease control program. As mentioned, the timeliness malaria diagnosis and treatment were fundamental for the elimination of human malaria, reservoirs as well as for the blocking of the transmission form humans to vectors. Consequently, it was instituted an individual and community-based identification network with grassroots level, decentralized health care and laboratory facilities to enable local vector control, early identification and management.

Once malaria has decrease to a few imported cases and zero autochthonous cases, we recommend integrating the VCs into the control of other infectious diseases like dengue without decreasing the malaria surveillance activities. The stratification of malaria geographic distribution in hypoendemic, meso-endemic and hyper-endemic areas was another important tool in the elimination of the disease; therefore, we propose the use of new technologies like Satellite Images (SI) and Remote Sensing (RS) to define risk area, places where imported cases emerge and the stratification. The stratification in hypo-endemic, meso-endemic and hyper-endemic areas using SI and RS can be a
powerful tool for any malaria control program. All these strategies were cost/efficient and did not implied a great financial investment which allowed to be maintained by local government resources and community contributions. This characteristic of the malaria control program maid it self-sustainable in El Salvador.

In addition, the malaria program in El Salvador became immune to political circumstances and equipped to sustain through natural disasters or other similar calamities. Regular periodic evaluation of the program and retuning, revising or renewing it according to the past results, current scenario and future predictions.

However, at the same time, the study also throws light on certain areas that, in spite of its success, El Salvador can incorporate into its malaria program to sustain its control over malaria and enable its elimination. We propose a detailed evaluation of age and gender-based incidence and focus of efforts on the more susceptible groups like immigrants and border populations. The Meteorological department should feed information to the malaria program in order to predict increases in the vector populations. Close monitoring of immigrant as well as emigrant population groups. Greater coordination with neighboring nations for cross border control. Institution of a setup to screen, identify and manage malaria at all ingress and egress points with the voluntary collaborators, laboratories and medical centers decentralized but focused towards these points.

Extending cooperation, policies and even funding across the borders to its neighboring countries thereby not just restricting its role within itself but as an example to the region and the world. Avoid premature end game declaration and realization of the fact that control of a disease can be local or national but the end game of eradication is
only, and only global. Preferred selection of medicos, epidemiologists, paramedics and local private medical practitioners as Voluntary Collaborators.

Figure 22. On June 20th 2019, in Wuxi, China, El Salvador was among the 7 American countries that may eliminate malaria by year 2020.

Source: Pan American Health Organization El Salvador

In June the 20th 2019, in Wuxi, China, it was carried out the 3rd Global Forum of Malaria-Eliminating Countries. These countries may eliminate malaria by year 2020. El Salvador was one of the 7 countries of the Americas that participated in this activity and was represented by the coordinator of the malaria program of the Ministry of Health, Dr. Jaime Alemán (As mentioned, I carried out my Internship at PAHO/Ministry of Public Health of El Salvador under the mentorship of Dr Alemán). El Salvador is close to completing its third year with zero indigenous cases of malaria. By completing three years of having zero indigenous cases, El Salvador will be able to begin the process of applying for the certification of malaria elimination.
Chapter 12: Gaps and lessons learned

The main lessons learnt from the El Salvador Malaria Program can be resumed in a strong grassroots community involvement through the CV network. The CVs worked even during the Civil War and were the executors of a 95% reduction of malaria cases during the Rapid Decline period 1981-1995. This legion of CVs allowed a timeliness diagnosis, diagnosis, diagnosis nans treatment of malaria cases in the community which allowed the cure of the patient but also the elimination of a human reservoir and the stopping of the transmission to the mosquito. The use of combined therapy Chloroquine + Primaquine allowed the killing of merozoites by Chloroquine while Primaquine killed hypnozoites and gametocytes. The use of Primaquine as public health measure to stop transmission to the vector has been recently used in field trials in Africa. The stratification of geographic areas in hyper-endemic, meso-endemic and hypo-endemic was another successful strategy that allowed the concentration of the resources in those most needed areas. Considering, we have new advanced tools like Geographic Information Systems (GIS), and Remote Sensing (RS) this stratification strategy can substantially be enhanced. Another important lesson from el Salvador is the fact that this small Central American country demonstrated to the world that “Malaria Can Be Defeated”. Moreover, they did so without a malaria vaccine. On the other hand, there are some gaps in the fight against malaria like the fact that there are very few drugs that can kill gametocytes and hypnozoites.
Also, the reintroduction of malaria is always a menace considering there is a lot of human mobilization in the borders with Guatemala and Honduras. We propose the establishment of a Malaria Passport which will be given to enter into the country after the traveler takes malaria chemoprophylaxis. The maintenance of the government support of the malaria program is crucial to keep a strong surveillance system and national policies to prevent the reintroduction of the parasite.
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Appendix A: PAHO Approval letter

Referencia: ELS-COO-010/61/4.3GAR

8 de agosto de 2013.

Srta. Tatiana I. Gardelini G.
Panamá, Panamá

Estimada señora Gardelini:

Tengo el agrado de informarle, que ha sido seleccionada para participar en el Programa de Pasantes y Voluntarios en la Representación de OPS/OMS El Salvador. Los términos de este programa son los siguientes:

Asignación
Usted trabajará en el área de Vigilancia de la Salud, Prevención y Control de Enfermedades, bajo la supervisión del Dr. Miguel Aragón. Adjunto encontrará copia de sus términos de referencia, que constituyen parte de este acuerdo.

Duración
Se espera que Usted trabaje del 12 de agosto de 2013 hasta 4 de octubre de 2013, 54 días/40 horas por semana.

Seguro de Salud y Accidentes
OPS le proveerá de cobertura para accidentes durante el período de su asignación y mientras permanezca en las instalaciones de OPS. Por favor note que Usted debe poseer su propia cobertura de seguro de salud y debe proporcionar prueba de este seguro, con una copia adjunta a esta carta firmada.

Remuneración
No hay remuneración para los Pasantes/Voluntarios.

Reglas y regulaciones
Durante este período de tiempo, Usted estará sujeta a la aplicación del Código de Conducta y Principios de Ética, Políticas de Prevención y Resolución de Acoso en el lugar de trabajo y al Código de Vestuario.

Empleo
Los pasantes/voluntarios no podrán ser considerados bajo ninguna modalidad contractual, ya sean como miembros o no del personal, por un periodo de tres meses después de haber completado su participación en el programa. Cualquier empleo con OPS/OMS deberá ser sujeto a los procedimientos de reclutamiento y selección.

Parientes en OPS/OMS
Usted confirma que no posee ningún vinculo familiar con un miembro activo del personal (incluye Consultores) en OPS/OMS (Oficina Central, Oficinas de País o Centros). Bajo los estatutos del personal los parientes se definen como:

- Sujeto a la Regla de Personal 110.7.3: El término “pariente cercano” se entiende el cónyuge, los hijos, los padres y hermanos del funcionario y los niños, los padres y hermanos del cónyuge del funcionario.
- Las personas estrechamente relacionadas de sangre o por matrimonio a un funcionario normalmente no serán nombradas si otra persona calificada está disponible. Las personas estrechamente relacionadas de sangre o por matrimonio incluye a un pariente cercano, tal como se define en Artículo 110.7.3. y a los abuelos, los nietos, los tíos, las tías, las sobrinas y sobrinos, así como a cualquier otro escalo de familiares, del funcionario o su cónyuge.
Confidencialidad

Usted acuerda que todo conocimiento e información que no sea del dominio público, que usted pueda recibir de OPS o de sus empleados en virtud de su voluntariado, durante el tiempo de su participación y para las finalidades del programa, será considerada y manejada por usted con carácter estrictamente confidencial, y no será directa o indirectamente revelada a cualquier persona, de ninguna forma, sin el permiso expreso y escrito de OPS.

Actividades de Pasantes/Voluntarios en OPS/OMS El Salvador

Usted acuerda participar en todas las actividades del programa durante su voluntariado en la Representación de OPS/OMS El Salvador.

Finalización de la Pasantía/Voluntariado

Usted acuerda completar una evaluación final y presentar un reporte final a su supervisor tanto como al Coordinador de Pasantes y Voluntarios. El reporte puede ser una presentación o un documento que resalte la experiencia y recomendaciones.

Si Usted está de acuerdo con los términos antes detallados, por favor firme abajo y devuelva a la atención de Dr. José Ruales, Representante de OPS/OMS El Salvador.

Atentamente,

[Signature]
Dr. José Ruales
Representante

Firma: [Firma]
Tatiana I. Gardellini G.

Fecha: 9 - Agosto - 18
Appendix B: Letter of recognition for Fellowship

Referencia: ELS-COO-01061/4.3GAR-1516

EL INFRASCrito REPRESENTANTE DE LA ORGANIZACIÓN PANAMERICANA DE LA SALUD / ORGANIZACIÓN MUNDIAL DE LA SALUD CON SEDE EN EL SALVADOR, HACE CONSTAR:

Que la Licda. Tatiana Itzel Gandiñé Guevara, participó en el Programa de Pasantes en la Representación de OPS/OMS El Salvador, asignada al área de Vigilancia de la Salud, Prevención y Control de Enfermedades, durante el período 12 de agosto de 2013 al 4 de octubre de 2013.

Y, para los usos que la interesada estime convenientes se extiende la presente en la ciudad de San Salvador, a los cuatro días del mes de octubre del año dos mil trece.

[Signature]
Representante
MEMORANDUM

Para: Dr. Julio Alberto Armero Guardado
   Director de Vigilancia Sanitaria

De: Ing. Arnoldo Rafael Cruz López
    Director de Salud Ambiental

A través de: Dr. Eduardo Antonio Espínoza Fiallos
            Viceministro de Políticas Sectoriales

Recibe un cordial saludo, por el presente hago la reseña de que en fechas del 12 de agosto al 4 de octubre tuvimos la visita de la Dra. Tatiana Gardellini Guevara, interna de OPS de la Universidad de Florida del Sur (UF) a quien se le brindó apoyo para su tesis de posgrado en el Salvador; la cual se relaciona con el tema de malaria. En tal sentido solicito su usual apoyo con el aporte de la información detallada a continuación:


No omito manifestarle que esta información debe ser enviada a la Unidad de Vigilancia y Control de Enfermedades Vectorizadas de la Dirección de Salud Ambiental, a más tardar el día viernes 28 de marzo del presente año.

Atentamente,

Ing. Arnoldo Rafael Cruz López/Director de Salud Ambiental
Dr. Jaime Enrique Almán Escobar/Técnico Médico Unidad de Vectores/Dirección Salud Ambiental
Dr. Miguel Acosta/Consultor de Control y Vigilancia de Enfermedades-OFS

MINISTERIO DE SALUD
VECTORES
MEMORANDUM

No. 2014-6100-216

PARA : Inq. Arnoldo Rafael Cruz López
Director de Salud Ambiental

DE : Dr. Julio Alberto Armero Guardado
Director de Vigilancia Sanitaria

FECHA : 22 de abril de 2014

Reciba un cordial saludo.


Sin otro particular me despido atentamente.


Calle Arce N°. 827, San Salvador, El Salvador
Teléfono 2205-7164 Fax:2205-7318
www.salud.gob.sv
Appendix E: PAHO Fellowship Certificate, El Salvador
## Appendix G: Data tables and maps from information retrieved from the Malaria Surveillance System at MSPAS El Salvador

### Table 4. Year wise distribution of positive cases by age group over the years (week 1 -52) 1994 to 2013

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<th>Year</th>
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<th>M</th>
<th>F</th>
<th>M</th>
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<th>M</th>
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Table 4. Year wise distribution of positive cases by age group over the years (week 1 -52) 1994 to 2013

Source: Department of malaria, Ministry of Public Health and Social Assistance, El Salvador.
Table 5. Order of Positive cases under different age groups over the years.

Source: Department of malaria, Ministry of Public Health and Social Assistance, El Salvador

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</tr>
<tr>
<td>Female</td>
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</tr>
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Table 6. Department wise Epidemiological Report of malaria cases Years during the year 1994-2013, Week 1-52

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Table 7. Department wise cases of Malaria reported over the period 1994-2013.

Source: Department of malaria, Ministry of Public Health and Social Assistance, El Salvador

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Figure 23. Municipalities with autochthonous malaria transmission. 2008-2010.
Source: Department of malaria, Ministry of Public Health and Social Assistance, El Salvador

Figure 24. Municipalities with risk of malaria reintroduction. El Salvador, 2005-2010.
Source: Department of malaria, Ministry of Public Health and Social Assistance, El Salvador
Figure 25. Autochthonous malaria cases, by Department and Municipalities. El Salvador, January to December from 2012.

Source: Department of malaria, Ministry of Public Health and Social Assistance, El Salvador

Table 8. Malaria Index Measurements

Source: Department of malaria, Ministry of Public Health and Social Assistance, El Salvador

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Sistema nacional de información de malaria
Figure 26. Physical Infrastructure for malaria control by departments. El Salvador.
Source: Department of malaria, Ministry of Public Health and Social Assistance, El Salvador

Figure 27. Malaria Case detection by VC and other health personnel EPI weeks 1-39, 1993.
Source: Department of malaria, Ministry of Public Health and Social Assistance, El Salvador