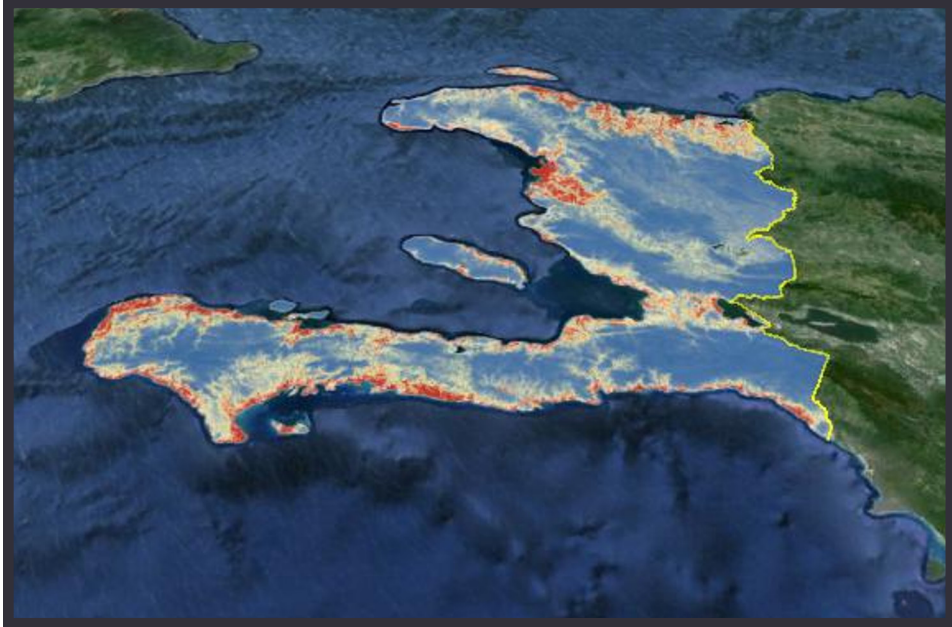

The feasibility of malaria elimination on the island of Hispaniola, with a focus on Haiti

An assessment conducted January–June 2013

Photo © 2012 Natalie Briggs/Global Health Outreach, Courtesy of Photoshare
In St. Marc, Haiti, two boys play with playdough while their parents are at the dentist.

The cover photograph is used for illustrative purposes only; it does not imply any particular health status, attitudes, behaviors, or actions on the part of any person who appears in the photograph.

Contents

ACKNOWLEDGEMENTS

This report was authored by the Clinton Health Access Initiative in close collaboration with the Haitian MSPP/Programme national de lutte contre le malaria, the Global Health Group of the University of California, San Francisco, David Smith of Johns Hopkins University, Azra Ghani, Griffin Jamie, and Lucy Okell of Imperial College, Andrew Tatem of the University of Southampton, and Linus Bengtsston from Flowminder.

It summarizes the work and contributions of many individuals, without whom this report would be impossible. In particular, we acknowledge the generous sharing of data by the Haitian MSPP/Programme national de lutte contre le malaria, the Dominican Republic's CENCET, the United States Centers for Disease Control & Prevention, Population Services International, Flowminder and Digicel, and all of the GFATM sub-recipients We gratefully acknowledge funding for this work from the UCSF Global Health Group. The below individuals were interviewed during the course of this project, and we thank them for their contributions:

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ABBREVIATIONS

AOPS	Association des Oeuvres Privées de Santé
ACT	Artemisinin-combination therapy
API	Annual parasite index
BCC	Behavior change communication
CAPS	Centre d' Appui aux Politiques de Santé
CARICOM	Caribbean Community
CIFAS	Centre d'Information et de Formation en Administration de la Santé
CDS	Centres pour le Développement et la Santé
CENCET	Centro Nacional de Control de Enfermedades Tropicales (Dominican Republic)
COD	Cash On Delivery
CHW	Community Health Worker
CMMB	Conseil Mission Médicale Catholique
CPNMFL	National Malaria and Lymphatic Filariasis Control Program at the Ministry of Health
DDT	Dichlorodiphenyltrichloroethane
DELR	Directorates for Epidemiology and Laboratory Research
DOSS	Direction d'Organisation des Services de Santé
DOT	Directly Observed Therapy
DPM/MT	Directorates for Pharmaceuticals and traditional medicine
DPSPE	Direction de Promotion de la Santé et de Protection de l'Environnement
DR	Dominican Republic
FOSREF	Fondation pour la Santé Reproductive des Femmes
GDP	Gross Domestic Product
GFATM	Global Fund to Fight AIDS, Tuberculosis and Malaria
GMEP	Global Malaria Eradication Campaign
IDCP	Instituto Dermatologico y Cirugia de Piel
IDP	Internally Displaced Persons
IEC	Information, Education, Communication
IHF	Innovative health financing
IPT	Intermittent preventive treatment
IRS	Indoor residual spraying
ITFDE	International Task Force for Disease Eradication
ITN	Insecticide-Treated Nets
LF	Lymphatic filariasis
LLIN	Long-lasting insecticide-treated mosquito nets
LNSP	National Laboratory
MARCH	Management and Resources for Community Health
MDA	Mass-drug administration
MSPP	Ministry of Public Health and Population
NGO	Non-government organization
ODA	Official Development Assistance
PAHO	Pan-American Health Organization
PESADEV	Perspectives pour la Santé et le Développement
PR	Prevalence Rate
PSI	Population Services International

RBM	Roll Back Malaria
RDT	Rapid diagnostic test
SNEM	Service National d'Éradication de la Malaria
SR	Sub-recipient
UADS	Unite d'Appui a la Decentralisation Sanitaire
UCP	Unit for the Coordination of HIV, TB, and Malaria/LF Programs
UPE	Unit for Planning and Evaluation
USAID	United States Agency for International Development
US CDC	United States Centers for Disease Control and Prevention
VDH	Volontariat pour le Développement d'Haïti
WHO	World Health Organization

EXECUTIVE SUMMARY

Objectives

This feasibility assessment was conducted to inform the governments of Haiti and the Dominican Republic (DR) as they work to achieve their joint goal of malaria elimination by 2020. This report was intended to complement the existing national and bi-national strategic plans by reviewing the status of the malaria programs, conducting detailed technical, operational, and financial analyses of what will be required to achieve elimination, and highlighting programmatic gaps that must be filled to achieve the goal of elimination by 2020. The feasibility of interrupting transmission in the great majority of the DR was demonstrated in the 1960s, although these successes could not be maintained as importation from Haiti increased in the 1970s. Accordingly, this assessment focuses primarily on evaluating the prospects for Haiti to eliminate malaria under the assumption that success in Haiti will be the key to sustainable elimination across Hispaniola.

History

The feasibility – and the challenge – of malaria elimination in Hispaniola is underscored by the very near success of eradication efforts in the 1960s. The DR succeeded in reducing malaria incidence to only 21 cases in 1968, while Haiti reduced slide prevalence rates to well below 1% despite testing over 1 million people that same year. These gains were not sustained however: financing proved insufficient, vector control alone failed to interrupt transmission in Haiti, and Haiti's mass drug administration program appears to have been designed with insufficient consideration for managing reintroduction by mobile populations. Despite localized success in interrupting transmission, national implementation was insufficient to consolidate these gains. Malaria resurged throughout the 1970s, first in Haiti, then, faced with persistent imported malaria from Haiti, in the DR. Learning from what worked and what failed in the previous elimination efforts will be important as Haiti and the DR design contemporary implementation plans to achieve elimination by 2020. Eliminating this final stronghold of the disease will mean all Caribbean islands will be malaria-free and will signify the completion of a regional campaign begun over 50 years ago.

Current response

In the DR the 2012 number of cases (952) malaria cases was the lowest in 15 years and suggests that the current malaria program, funded by the national government with the support of the GFATM, the US CDC, and PAHO, is having substantial impact in reversing the increasing trend in malaria incidence that occurred there throughout there much of the last two decades. The program consists of a mix of vector control for prevention and case detection and response. In Haiti, recent prevalence and slide positivity rates have been substantially lower than historically reported; a population-representative survey detected parasite prevalence <1% in 2011. Current efforts have involved vector control measures including the distribution of insecticide-treated nets, supported by the GFATM, while partners including local NGOs and the US CDC are working with the government to improve surveillance systems and case management.

Technical assessment

Review of available data on malaria incidence and prevalence in Haiti identified few reliable datasets. The Haïti Système d'Information Sanitaire, the health management information system to which the approximately 800 health facilities across Haiti report, was found to be too incomplete for analysis.

National surveys recently completed by Population Services International were extremely useful for understanding national prevalence and trends but were insufficient for understanding heterogeneity across the country. Only data from the National Sentinel Site Surveillance System, a reporting system supported by the US CDC that currently covers 107 health facilities, was found to be sufficiently comparable across facilities to permit analysis. Information on the number of confirmed and suspected cases at these health facilities were modeled as a function of environmental and demographic covariates to construct an initial map of estimated malaria positivity rates across Haiti. Overlaying this map with maps of population suggests that a third of Haiti's population lives in areas of no or negligible transmission risk, while a quarter (over two million people) lives in areas at medium or high risk.

Although national prevalence is <1%, the risk map suggests substantial heterogeneity is occurring across Haiti, and individual foci are likely to have substantially higher Prevalence Rate (PR) than this national average. Individual-based stochastic models were used to simulate the potential for a variety of attack measures to eliminate malaria within foci of 10,000 people. Simulations of the impact of net distribution suggests that the current strategy of universal coverage with nets is likely to reduce prevalence but will not achieve elimination. Simulations of indoor residual spraying of insecticide mirror Haiti's actual experience in the 1960s: they suggest malaria can be greatly reduced but not eliminated through such a strategy because of the propensity of the primary vector, *Anopheles albimanus*, to bite and rest outdoors. To eliminate, modeling suggests – as per the actual Haitian experience of the 1960s – that complementing vector control with an attack on the parasite reservoir in humans will be necessary.

Simulations tested parasite-based strategies in which individuals in high prevalence foci were tested with rapid tests and positive individuals were treated with either chloroquine or artemisinin-based combination therapy (ACT) in combination with primaquine, as well as foci-based strategies in which the entire population of an identified high prevalence foci was treated. Results suggest that five years of treating more than 90% of individuals testing positive in more than two annual rounds of testing during the low transmission season would achieve elimination in low to medium risk foci. But in the highest risk foci treating more than 90% of all individuals within the foci without prior testing was more likely to lead to successful elimination as tests would miss too many infections. Elimination was more likely to be achieved in smaller communities, with a greater number of testing and treatment rounds per year, if higher coverage was achieved in each round, and if drugs are distributed randomly from round to round rather than missing the same individuals each time. Understanding how best to implement such interventions geographically will require understanding patterns of human and parasite mobility. Preventing the resurgence of malaria transmission after elimination will require an enhanced passive surveillance system and operational outbreak response team; simulations showed that after elimination has been achieved, more than half of imported malaria infections should be detected and cured to maintain malaria-free status in the country.

Operational assessment

Semi-structured interviews were conducted with government personnel, former employees of the eradication program, malaria program managers, and leaders of organizations working in malaria in Hispaniola. Reports on the malaria programs were reviewed, and group discussions were facilitated at the Haitian Salle de Situation, the quarterly Sub-Recipient meeting for the GFATM grant, and, on a more limited scale, with the staff of the program in the Dominican Republic. Results of this assessment suggest that there are substantial operational constraints to elimination in Haiti. Programmatic realignment and support from partners will be required to strengthen and reorient the current control program towards elimination. Three broad areas in which operations must be strengthened were identified: first, stronger surveillance systems to identify, treat, and swiftly report malaria infections,

including both passive and active measures, must be put into place, and means of using these systems to direct elimination activities must be devised; second, anti-malaria interventions, potentially including both vector control and parasite-focused measures, must be targeted in an evidence-based way towards specific transmission foci, and organizational and logistical systems must be constructed that can facilitate scale-up to sufficiently high coverage levels; third, the government's capacity to lead and coordinate the elimination program must be improved, and more detailed plans for how an elimination program is to be conducted and monitored by the government and its partners are required. Conducting the sort of parasite-based testing and treatment campaigns suggested by the technical assessment will require a substantial program of community outreach to ensure acceptability and compliance, and a great expansions in malaria staff will be required to carry them out; the experience of ongoing mass drug administration efforts for lymphatic filariasis suggest that doing so will be possible, if challenging.

Financial assessment

Estimated budgets were constructed for hypothetical elimination scenarios in Haiti in which parasite-based attack measures complemented with vector control would be targeted to known transmission foci, assumed per the technical assessment to include more than 2 million people. The annual costs to maintain the current program involving only passive surveillance and occasional net distribution were estimated to run approximately US$9 million annually on average. Converting such a program to an elimination program focused on treating all individuals in high-risk foci for five years was estimated to cost approximately US$18 million a year for five years, although these costs may be substantially reduced if improved surveillance data permits more specific definition of where foci occur. In a second scenario, costs were estimated for a hypothetical scenario in which mass testing of all individuals living in high risk foci is first conducted over two years to define where infection occurs, and then treating all individuals in the more well-defined foci over the subsequent three years. Such a program would cost approximately US$23 million a year for the first two years, and then only about US$10 million a year for the following three. The majority of costs in both scenarios was estimated to be related to purchasing of drugs and diagnostic tests, as well as to the large scale communication campaigns required to ensure community acceptability of such programs. Costs are estimated to fall dramatically after elimination is achieved given the assumption that importation of new malaria infections from abroad is very low. Some ongoing costs will be required to maintain strong surveillance, including testing of suspected malaria cases, to ensure that malaria transmission is never reestablished, but many of the ongoing costs of the malaria control program (such as distribution of bed-nets) could be halted. As a result, it is plausible that elimination could prove net cost saving within a decade, a far more optimistic result than has been suggested for countries in other contexts where substantial investment is assumed to be required even long after elimination is achieved.

Limitations

The initial risk map presented here is based on positivity rates reported by a subset of health facilities. Inconsistent definitions and interpretation of the denominator, "suspected malaria," are likely to influence results, as are spatial patterns in blood testing rates across Haiti. Additionally, the map assumes transmission occurs at the location of the health facility since no information on patient household location is available. Refinement of these maps should occur in partnership with the CDC, which is working on the ground to strengthen and expand this system. Implementation of active follow up to geolocate patient households will greatly improve the accuracy of future maps.

Models represent a simplified version of the world. There is some variability around any average model outcome, as each simulation iteration may provide different PR estimates for the same set of input data.

In addition, results of simulation modeling are very sensitive to a few assumptions, such as the type of drugs used and the way they are distributed; in particular, results depend upon the size of the community being modeled. In small communities of only a few hundred people, simulations suggest parasite-based attack measures are much more likely to successfully eliminate malaria than in large communities of many thousands of people. More precise surveillance data will be required to understand the true population sizes of high risk foci and thus the probability of success through such a treatment campaign.

Budget estimates for the hypothetical elimination programs outlined here are very rough, and true costs will depend upon the precise plan devised by the malaria program. Additionally, we have based costs upon the assumption that the estimated >2 million people living in areas of moderate to high risk must be targeted simultaneously to achieve elimination. In reality, a spatially progressive approach involving intensive but staged attack may permit cost savings. The actual populations living in risk areas must be determined more precisely as better surveillance data become available.

Next steps

This assessment suggests that malaria elimination is technically feasible in Hispaniola by the target year of 2020 if substantial resources can be devoted to strengthening the malaria program in Haiti and reorienting it towards elimination. Further field testing, validation, and methodological improvements will be required to confirm these results and ensure they accurately inform a detailed operational plan for achieving elimination. Determining what interventions will be most effective at achieving it will require testing and evaluating a variety of different strategies in different transmission contexts; supporting the government in beginning such trials soon will be critical for ensuring the malaria programs can devise specific implementation plans based upon a strong evidence base. Surveillance strengthening, including ensuring all fevers are tested, treated, and reported appropriately at health facilities, is also essential to improving knowledge about where malaria occurs and at what intensity across Haiti. Ensuring existing funding from the GFATM is used effectively to help prepare for elimination should be a high priority. Haiti has many partners already supporting anti-malaria activities; their coordination and support to the Ministry of Public Health and Population will be crucial as Hispaniola moves towards elimination.

INTRODUCTION

Background

During the 1950s-1970s, about 70 countries around the world succeeded in eliminating malaria.[1] Under the Global Malaria Eradication Campaign (GMEP) of the 1950s and 60s, countries aimed to "eradicate" malaria, which involved reducing malaria transmission through active measures to the point that no indigenous cases of malaria occurred for three years.[2] Today, the World Health Organization defines malaria "elimination" as the "absence of clusters of three or more epidemiologically-linked autochthonous malaria cases due to local mosquito-borne transmission, nationwide for three consecutive years."[3] Only a dozen countries have achieved this goal since 1980.[4] Moreover, many countries that had come close to elimination, including Haiti and the Dominican Republic, have experienced resurgence, largely due to funding shortfalls.[5]

Today, it has been suggested that malaria elimination of both *Plasmodium falciparum* and *P. vivax* is potentially more feasible in the Americas than anywhere else in the world.[6] Haiti and the Dominican Republic, the two countries that comprise the island of Hispaniola, and the only remaining Caribbean island with endemic malaria, are currently estimated to be the only countries in the Americas at risk of transmission by *P. falciparum* but not *P. vivax*,[7,8] an important consideration for elimination feasibility given that *P. vivax*'s propensity to cause relapses of disease for months or even years makes it substantially more difficult to eliminate than *P. falciparum.*[4] Moreover, the International Task Force for Disease Eradication (ITFDE), led by the Carter Center, stated that a program for elimination of malaria and lymphatic filariasis from Hispaniola specifically is not only technically feasible, but also "medically desirable, and would be economically beneficial to both the Dominican Republic and Haiti."[9]

Elimination is the stated goal of the National Strategic Plans of both Haiti and the Dominican Republic, and both countries have secured GFATM grants to begin working towards this achievement. Recognizing that elimination will require a coordinated approach across the island, the two malaria programs and ministries of health have come together to commit to a bi-national strategy with the goal of elimination by 2020. That strategy, currently under revision, suggests that elimination can be achieved with two years of transition and build-up, three years of coordinated attack with long-lasting nets, and five years of coordinated consolidation. The estimated budget for this plan is US$193.9 million, of which US$121.8 million is for Haiti.

The bi-national plan provides a high-level agreement for targeting elimination by 2020, but specific operational gaps remain to be filled in. In Haiti, where 96% of the island's cases occur, surveillance currently relies on the identification and treatment of cases diagnosed passively through the health systems. This has helped the country reduce its malaria burden substantially but will be insufficient to interrupt transmission.[10] At the same time, Haiti has conducted a national distribution of insecticide-treated bed-nets (ITNs) funded through its GFATM grant, but ITNs alone may be insufficient for achieving elimination[11] given the exophily of Haiti's primary vector, *Anopheles albimanus*.[12] Optimal strategies to accelerate Haiti towards elimination are required, but considerable operational and financial challenges exist that could be roadblocks to their success.

Overcoming these challenges and achieving elimination on the island of Hispaniola would remove one considerable burden on Haiti's overstretched health system and would free other Caribbean countries and the United States from responding to outbreaks seeded by exported malaria from Hispaniola. Eliminating this final stronghold of the disease will mean a malaria-free Caribbean and the completion of a regional campaign begun over 50 years ago.

Objectives and overview

This feasibility assessment was conducted to inform the Governments, and particularly the Haitian Ministry of Health (MSPP), on efficient strategies to achieve elimination by 2020. This report was intended to complement the existing national and bi-national strategic plans by making detailed technical, operational, and financial analyses of potential intervention approaches and drawing data-driven operational recommendations for their implementation. This report is structured around the following questions:

1. **Technical feasibility**
   What is the epidemiology of malaria in Haiti, and what interventions will be needed to achieve and maintain elimination?
2. **Operational feasibility**
   What program and system-level capacity building will be necessary to ensure timely and effective implementation of these technical recommendations?
3. **Financial feasibility**
   What would the cost be of achieving and maintaining elimination? How does this compare with current financing and how can the financing gap be reduced?

Using this new evidence base, the MSPP can present a strong investment case to donors for the financing required for elimination targeting the most effective interventions in the areas at greatest risk.

This feasibility assessment draws on a similar assessment conducted in Zanzibar and analyses were guided by the Elimination Scenario Planning tool being developed by the WHO.[13] Both of these documents stress the importance of a country-specific strategy that assesses technical, operational, and financial feasibility. This categorization comes from analysis of lessons learned from the GMEP.[14]

For the technical assessment, a map of estimated malaria prevalence was generated from national surveillance data in combination with correlated environmental factors like rainfall and elevation. To better understand temporal and geographic trends, qualitative information was collected from existing surveys and research as well as interviews with the government, NGOs, and experts in the field. Finally, a wide variety of intervention scenarios were modeled in order to estimate the coverage and time required to achieve elimination.

Given the relative advancement of the malaria program in the Dominican Republic and the lower prevalence, the focus of the operational assessment was to determine the needs for Haiti's National Malaria Program. Investigators conducted this needs assessment through more than 30 qualitative interviews with government directorates within and outside of the Ministry of Health, donors and the United Nations, and NGOs including all recipients of the GFATM grant. Respondents were asked both about the current status of the program and broader health systems, as well as what would be required were there to be a dramatic scale-up of interventions. In addition, quantitative analysis of monitoring and evaluation data was conducted, including a mapping of existing interventions by sub-recipients of the GFATM grant.

For the financial assessment, a costing model was created using the current GFATM grant budgets and expenditure as a baseline. These expenditures were then modified or scaled-up according to the technical and operational recommendations. For new interventions such as mass drug administration and screening and testing, a model was created drawing on similar efforts in other countries. Where possible, the unit costs used for this assessment were built from standard costs identified in a recently

conducted study for Haiti's HIV National Strategic Plan and then compared against those seen in similar campaigns across different contexts.[15] The cost of elimination was then compared to total committed financing, as assessed and submitted as part of the proposal for the most recent GFATM grant, which extends through 2015. Recommendations to close the financing gap were made based on literature review and efforts currently being supported by the Clinton Health Access Initiative in other countries.

Summary of Key Data Sources	
Technical Feasibility	• National surveillance data (HSIS, NSSS) • Parasite prevalence and behavioral surveys • Entomological studies and other research • Haiti ecological maps • M&E data • Government interviews • Stakeholder Interviews • GFATM grant agreement
Operational Feasibility	• Stakeholder and government interviews • M&E data
Financial Feasibility	• GFATM budgets and expenditures • Counterpart financing evaluation conducted for the most recent GF grants • Literature review

History of malaria in the Caribbean

Research suggests that the malaria parasite came to the Americas by ship along with European settlers seeking new lands. The *P. vivax* parasite was most likely spread to the Caribbean by Spanish and French settlers, while the more deadly *P. falciparum* parasite was brought over during the slave trade at the end of the 15th century.[16] There, parasites met a ready supply of anopheline mosquitoes that were efficient vectors for the disease. The Caribbean and parts of Central and South America were affected first and then in the mid-18th century, malaria spread across the North American continent.[17] Large-scale, single-crop (such as sugar), tropical plantations contributed to the spread of malaria in the Caribbean by creating breeding opportunities for malaria vectors, exposing susceptible populations to infection, and facilitating the movement of malaria parasites.[16]

Limited evidence is available to evaluate the true burden of malaria's history in the Caribbean. In the early 1900s, malaria accounted for one-fifth of all deaths among British troops in the Caribbean.[18] By the 1930s, malaria-related morbidity rates were highest in the Windward Islands, St. Lucia, Grenada, and Dominica, all of which have since achieved elimination.

In 1954, the XIV Pan American Sanitary Conference resolved to eradicate malaria from the Americas. This campaign focused primarily on spraying households with insecticides, principally DDT. It was recommended to spray insecticides twice a year, but this recommendation was accomplished primarily in smaller countries (including Caribbean islands), while larger South American countries tended to struggle to accomplish more than one round per year due to the operational challenges of doing so.[19] Progress towards elimination during this campaign is illustrated for a selection of Caribbean islands in the below figure; all achieved elimination by the 1970s.

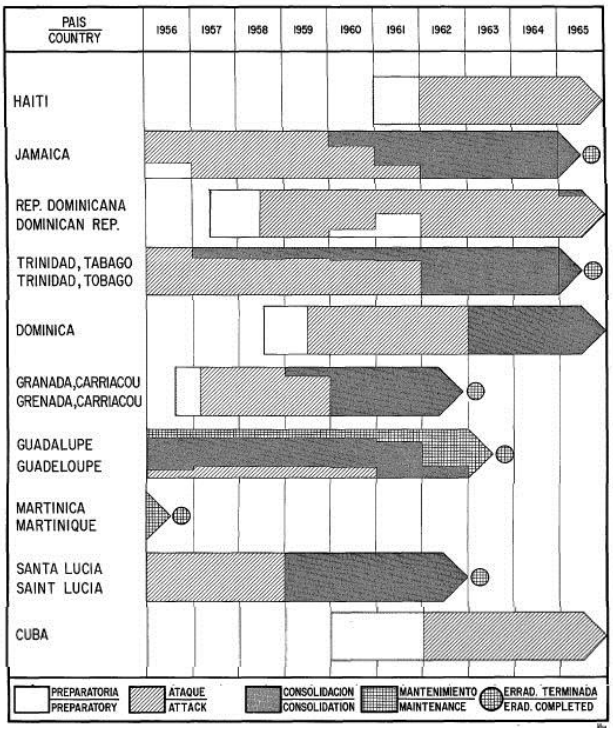


Figure 1. Progress towards "eradication" during the 1950s and 60s in a set of Caribbean region countries. Modified from (20).

Though the Caribbean used similar vector control efforts to other regions, the region experienced a higher success rate, due to the islands' small sizes, relative isolation, and ability to restrict the reintroduction of malaria from outside.[16] Moreover, these countries advanced their programs by promoting the participation of general health services in surveillance activities, with the ultimate goal of integrating malaria within health system activities.[21]

Box 1. Case studies of malaria eradication through vector control in the Caribbean

Cuba

After vector control efforts during the US army occupation in the early 20th century, malaria in Cuba was largely localized in the eastern part of the country. In 1962, there were 3,519 confirmed cases of malaria reported and Cuba established the National Service for the Eradication of Malaria, to use vector control measures, attack transmission foci, and conduct surveillance of febrile patients throughout the country. After initial efforts that focused on drainage of standing water and anti-larval control, in the early 1960s Cuba adopted repeated spray rounds with DDT to attack the vector, *An. albimanus.* Cases of malaria subsequently dropped annually from 1,325 in 1960 to 4 in 1968. WHO certified Cuba as malaria free in 1973.

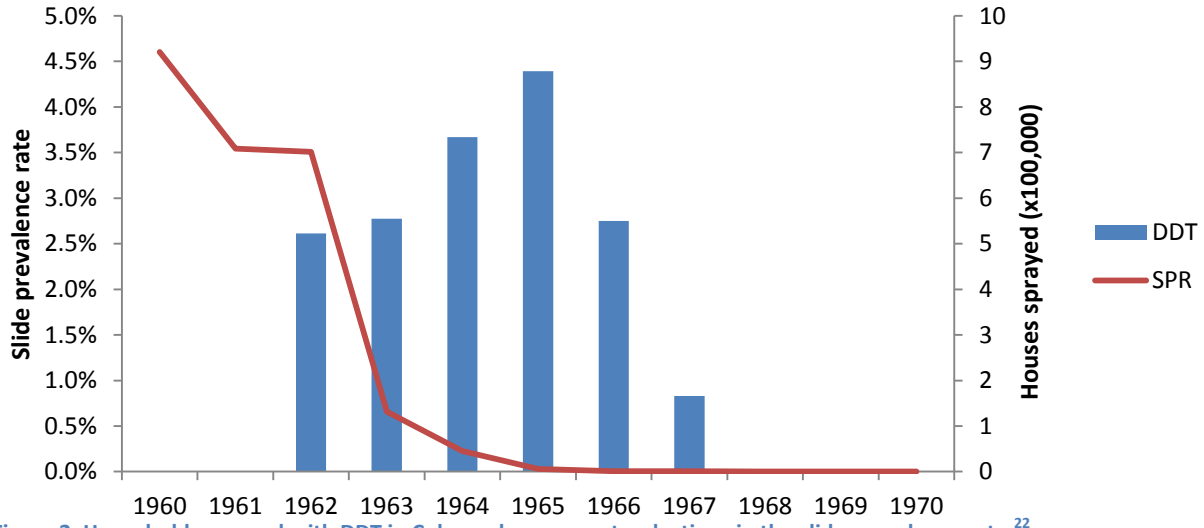


Figure 2. Households sprayed with DDT in Cuba and concurrent reductions in the slide prevalence rate.[22]

St. Lucia

In St. Lucia, malaria mortality rates from 1933-1942 were 200 per 100,000 and from 1943-1956 were 84 per 100,000 population.[23] Prevalence was found to be 12.9% in 1943,[24] and *An. aquasalis* and *An. argyritarsis* were the only potential vectors identified. A control campaign was initiated in 1953, but re-oriented towards elimination in 1956. The campaign consisted of DDT residual spraying of all houses at intervals of six months. In addition the campaign included the parasitological examination of blood films from – and the administration of single-dose antimalarial therapy to – all persons with fever or a history of fever. Spraying operations were suspended in 1959, with no evidence of resistance. Morbidity rates per 1,000 population fell from 75.2 in 1952 to zero in 1960, while the mortality rates per 10,000 during the same period fell from 13.2 to zero.[25]

Despite their current status as being malaria-free, Caribbean countries are still home to effective vectors and a malaria-naive population which has not experienced the disease for a generation or more, and

they import malaria cases on an ongoing basis from endemic neighbors.[26] Refugees from Haiti have been found to be infected with malaria, for example, potentially leading to movement of parasites from Haiti and other Caribbean countries.[27] Since elimination, vector control programs in these countries have weakened and malaria expertise is scarce, leading to slow reaction to epidemics caused by imported cases.[28] In recent years, there have been malaria outbreaks in the Bahamas, Trinidad and Tobago, and Jamaica, which required significant effort and resources to control. The outbreak in Jamaica was traced back to Haiti. After 44 years of no malaria transmission, there was an outbreak of *P. falciparum* malaria with 406 confirmed cases from September 2006-December 2009.[29] The Ministry of Health launched an emergency response focused on early detection and prompt treatment of cases, public education, and vector control, which successfully removed the threat.[29]

These countries would stand to benefit from the reduced risk of importation achieved through elimination on the island of Hispaniola. In September 2001, there was a meeting of the countries of the Caribbean Basin that are free of transmission but where imported cases are detected and vectors of the disease exist. These countries agreed to join a Roll Back Malaria (RBM) Initiative in 2002, to prevent the re-establishment of malaria transmission and to strengthen imported case detection capacity and clinical management.[30]

Malaria on the island of Hispaniola: context

HAITI

Haiti has a population of over 10 million people, 45.2% of whom live in rural areas.[31] More than half of the population lives in households that are below the extreme poverty line of US$ 1 per person per day. Unemployment rates are high, particularly in the capital of Port-au-Prince metropolitan area where they reach almost 50%.[32]

Table 1. Demographic variables for Haiti and the DR.

Indicator	Haiti	DR
Population (2013 est)	10.2 M	10.1 M
Median Age (2013 est)	21.9	26.8
Degree of Urbanization (2010)	52%	69%
Life Expectancy at Birth (2013)	62	77
Health Expenditures as % of GDP (2010)	6.9%	6.2%
GDP (PPP) (2012)	US$12.92B	US$98.74B
Mean Years of Schooling	4.9	7.2

Haiti is situated in the area of Hispaniola that is chiefly mountainous, making access to essential services extremely difficult. According to the 2005-2010 National Strategic Plan for Health Sector Reform, less than 40% of the population has access to basic health services in certain departments.[32] Illustrating the impact of structural barriers to healthcare, the country's maternal mortality rate is 630 per 100,000 live births and has increased in the past two decades.

The island is faced with frequent natural disasters. The 2010 earthquake resulted in the loss of over 200,000 lives and forced 1.5 million people into temporary camps and shelters. An estimated 500,000 people migrated from the area around the capital city to other regions that were less affected by the earthquake. As of January 2013, there were an estimated 400,000 still homeless, most of whom were sleeping in camps. In 2008, Hurricane Hanna resulted in 537 reported deaths. Following Hurricane Flora

in 1964, it was estimated that 70% of the houses were destroyed and that more than 75,000 cases of malaria subsequently occurred over a four-month period.[33]

DOMINICAN REPUBLIC

The 10 million inhabitants of the Dominican Republic are separated from Haiti by the Dajabón river. The Dominican Republic has experienced significant urbanization from 1970 to 2002 as the proportion of the population living in urban areas rose from 35% to 63% and was estimated at 66% in 2010. While a national banking crisis in 2003 led to a spike in extreme poverty, as of 2010, 10% of the population lives on less than US$ 2/day. The Dominican Republic has a GDP five times greater than Haiti as the tourism sector brings in substantial revenue (US$4.2 billion in 2008) and provides employment for approximately 195,519 workers. Seventy-five percent of the population lives within 2 km of health services. The maternal mortality rate in the Dominican Republic is 159 per 100,000, which is lower than in Haiti but still far short of the Millennium Development Goals.

Like Haiti, the Dominican Republic is susceptible to hurricanes. Annual spikes in the number of cases of malaria have been linked to climatic phenomena, such as Hurricane George (1998) and Hurricane Jeanne (2004). Outbreaks of the disease are also associated with migration of Haitians and movements of groups of migrant workers following temporary work in agriculture and construction.[34]

There are three official crossings along the 382 km border between the Dominican Republic and Haiti but there are also countless uncontrolled crossings that create a flow of people, goods, and diseases. It is estimated that over 1 million Haitians and Dominicans of Haitian descent live in the country, quite a few illegally, often participating in the labor market in construction, tourism, and other informal industries. There are also a considerable number of people of both nationalities who cross back-and-forth on a daily basis to work. CENCET has reported that since 2009 there has been a rise in imported cases of malaria.

The vector and parasite

Historically there were accounts of *P. vivax*, *P. malariae,* and *P. falciparum* on the island. Today, however, *P. falciparum* accounts for an approximated 99% of new infections, with the other 1% suspected to be imported cases of *P. vivax*.[35] This is an advantage for elimination efforts as more is understood about *P. falciparum* and, unlike *P. vivax, P. falciparum* lacks a dormant liver stage and thus will not relapse after effective treatment.[36] Moreover, the island benefits from the fact that the parasite is not resistant to cheap, safe, and effective chloroquine treatment.

Several species of Anopheles mosquitoes are common in the Caribbean, including *An. albimanus, An. crucians, An. vestitipennis*, and *An. grabhamii*.[26] All four of these species have been identified in Hispaniola,[37,38] but *An. albimanus* is considered to be the primary vector of malaria,[39] as has been suggested was the case in 17 out of 20 countries in the Caribbean region before the eradication campaigns of the 1950s and 1960s.[40] *An. albimanus* has been described as "primarily a coastal mosquito",[33] breeding in a wide variety of sunlit pools.[39] *An. albimanus* is considered a lowland mosquito[12] and is primarily found at elevations of less than 400 meters.[41] Biting is most common in the evening, with peak rates identified from 1730 to 2100 hours in Haiti.[39] The majority of its biting occurs outdoors,[12,39] and studies suggest that the vector rests outdoors.[12,41] Due to the outdoor resting and feeding behavior, past elimination efforts involving spraying residual insecticide in human dwellings may not have been effective against *An. albimanus*:

"In January 1962, DDT house spraying was initiated on a total coverage basis ..., twice a year. For the first five rounds the coverage and quality of spraying operations were considered as satisfactory (Evaluation Report 1964); at that time, it was concluded that the persistence of transmission observed in some highly malarious areas could not be attributed to deficiencies in spraying operations. It was stated that the basic difficulty was the considerable exophily and exophagy of the principal vector A. albimanus, coupled, unfortunately, with the extra-domiciliary habits of the population."[42]

Moreover, in the 1980s the vector developed resistance to DDT, though it remains sensitive to other insecticides.[35]

In Haiti, malaria is reported to follow seasonal increases in rainfall by about two months.[43] Rainfall is variable across the island, ranging from 400 mm to more than 3,000 mm in certain areas. There are two rainy seasons: from November to January and then a second more moderate season from May to July.

Malaria on the island of Hispaniola: history of the response

DOMINICAN REPUBLIC

In the early 1900s, malaria was reported to be a leading cause of morbidity and mortality in the Dominican Republic. From 1941 to 1964, anti-malaria interventions were conducted by the Malaria Division of the Ministry of Public Health, which was converted into the Servicio Nacional de la Eradicación de la Malaria (SNEM). Dieldrin spraying began in 1958, and DDT spraying in 1960, though it took until 1963 for the program to achieve sufficient coverage.[20] The annual budget ran US$1.1 to US$1.3 million in 1964-1966 dollars.[20] Thereafter, progress was swift and substantial: in 1968 only 21 cases of malaria were reported[44] and elimination seemed inevitable (Figure 3).

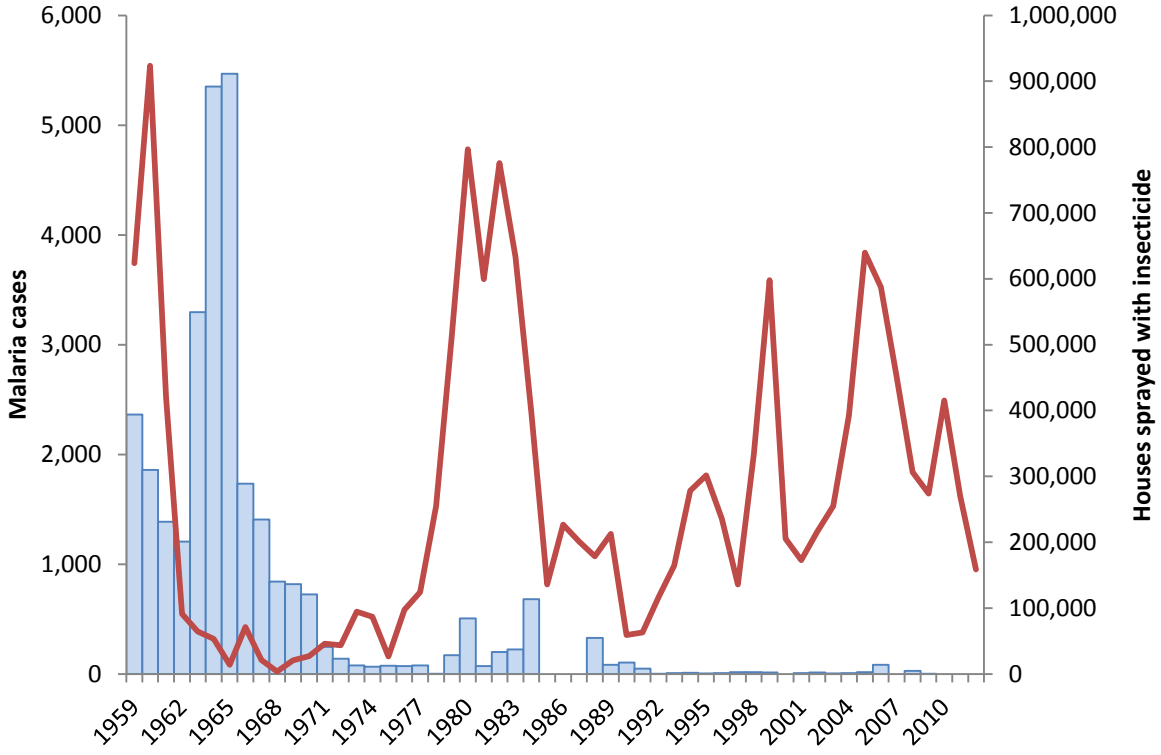


Figure 3. Malaria cases and indoor residual spraying in the Dominican Republic, 1959-2012.[45]

The program moved to the "consolidation" phase by 1968 in nearly the entire country, representing 90% of the population in formerly endemic areas,[22] with only a small area on the Haitian border considered to maintain malaria transmision.[46] With transmission believed interrupted everywhere else in the country, PAHO recommended maintaining insecticide spraying in the border regions as long as endemic malaria continued in Haiti, while building a strong surveillance system to maintain the gains.[21] Three years passed with no local transmission outside the border region. However, imported malaria from Haiti posed a serious challenge to maintain elimination. In July of 1976, importation sparked an outbreak of 200 cases that was successfully controlled.[47] As the epidemiological situation in Haiti deteriorated, importation increased, and with it, the challenge of suppressing it. In 1979, transmission was reestablished in several foci. The reestablishment was blamed on migration of infected workers from Haiti and insufficient surveillance.[48] At the same time, insufficient financial resources were available to attack the newly active foci.[49]

Attack was resumed in the early 1980s, temporarily stemming the malaria resurgence. Cases fell from a peak of 4,780 in 1980 to 816 in 1985. Indoor spraying was conducted in high risk areas, while potential breeding sites along the Haitian border were cleaned and stocked with larvivorous fish. However, increases in migration from Haiti continued to challenge the program with new inflows of parasites[50] even as resources remained insufficient to deal with them.[51] The strong connectedness between malaria in Haiti and the Dominican Republic is illustrated in Figure 4. In the 1990s, the program was decentralized to 34 Provincial and Health Municipal Bureaus,[44] and malaria incidence continued to trend upwards. In 1999, SNEM became the Center for Control of Tropical Diseases (CENCET) with responsibility for malaria, dengue, lymphatic filariasis, and intestinal parasitism.

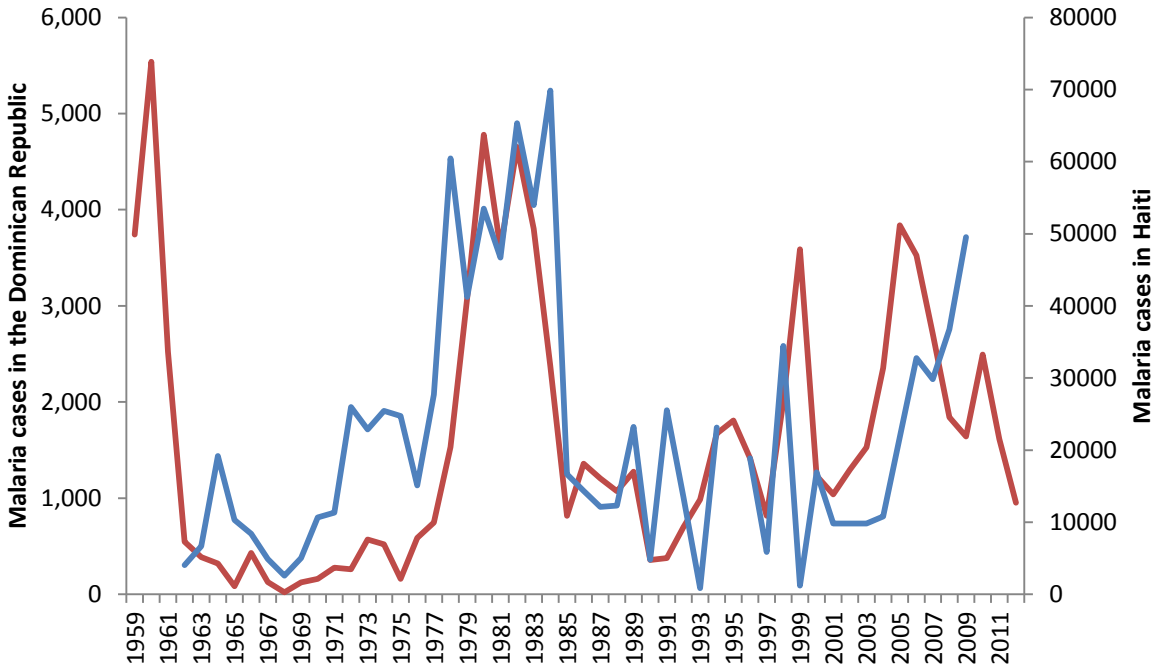


Figure 4. The success of the malaria program in the Dominican Republic has been closely linked to success in Haiti. Malaria cases in the DR (red) are shown on the left axis, while the substantially higher case count in Haiti (blue) is shown on the right.[45]

HAITI

Studies undertaken from 1915 to 1964 indicated that malaria affected a substantial fraction of the Haitian population.[52] In 1928, a prevalence survey found 23.5% of workers and 50.5% of children under 14 infected with malaria parasites.[38] Surveys of nearly 12,000 school children carried out in 1940-1942 by the Rockefeller Foundation found a parasite rate of 31%.[53] At that time 88% of the infections were caused by *P. falciparum*, 10% by *P. malariae*, and two percent by *P. vivax*. Parasite surveys in the Artibonite Valley indicated that 30% of the population were infected with malaria in the 1950s.[52]

The *Campaign Contra Insects* was just one of several attempts to begin an elimination campaign in Haiti. During the 1940s-50s, anti-malarial activities, primarily consisting of permanent drainage and public works projects, were initiated to reduce transmission. In 1950, targeted spraying with DDT began. In 1961, an agreement between the Government of Haiti, UNICEF, WHO/PAHO, and the United States Government created an official malaria eradication program. This agreement formed the *Service National d'Éradication de la Malaria* (SNEM), which was co-directed by the Haitian government and PAHO with USAID providing support.[54]

In January 1962, prior to the start of organized attack measures, a survey found a prevalence of 6.5%.[54] At this time, the program defined a malarious area including 3,200,000 people residing in 950,000 households at elevations below 500 meters, since it was believed *An. albimanus* could not be found at higher altitude. As in other Caribbean countries, the campaign involved biannual intradomiciliary DDT spraying. Nationwide spraying began in 1962.

Surveillance relied upon a network of health posts staffed by volunteers. There were 449 such posts in 1962, increasing to 807 in 1964 and 5,000 in 1968.[43] The volunteers collected slides from fever cases and provided educational materials to the general public.[52] Though there were never more than 7,000 volunteers, USAID evaluations recommended scaling up volunteers to 18,000.[55] The volunteers were supervised by malaria service personnel, who visited an average of 60 posts each month. In addition to the slides, an annual survey was conducted to monitor progress. One year after spraying had began, prevalence had fallen from 6.5% to 1.3%, yet in the subsequent year it rose again to 3.5%.

The failure to interrupt transmission altogether in regions where five rounds of satisfactory DDT coverage had been achieved was considered problematic.[43] It was thought probable that the common practice of re-plastering and painting interior walls combined with damage from a devastating 1963 hurricane may have been responsible. Blame was also attributed at least in part to the exophily and exophagy of the vector.[42] To address these problems, the time interval between spray rounds was reduced to only three months. Unfortunately, the doubling in the number of spray rounds meant that the budget was only sufficient to cover half as many houses as planned; 520,000 households were accordingly not sprayed.[43]

The increased number of rounds proved not to be any more effective than biannual spraying at fully ending transmission. Other programs facing similarly persistent transmission at that time began adopting the mass distribution of anti-malarial drugs; in Trinidad, for example, monthly drug administration successfully eliminated persistent low level transmission.[56] A mass drug distribution trial was thus begun amongst 45,000 residents of Petit-Goave in 1964. Combination tablets comprised of chloroquine and pyrimethamine were given to the entire population at three-week intervals, and DDT spraying was halted in the region. Coverage in the pilot population of over 90% was achieved through the first 15 distribution rounds, and as a result slide positivity declined from 15% after the first round to <1% three months later (no such decline was observed in surrounding areas during the same period).[43]

This pilot was considered a sufficient success that it was expanded nationally to all who were considered to be living in high risk areas beginning in May 1965. In areas neighboring these high risk zones, active case detection procedures were implemented. This work consisted of monthly door-to-door investigations to find and test febrile individuals, with the goal of identifying regions with ongoing malaria transmission that could be added to those receiving drug administration. Areas considered at low risk continued to have only passive detection via the network of volunteer health posts.

As in the pilot, DDT spraying was halted before mass drug administration began, though it was restarted the following year. Drug administration was not conducted everywhere simultaneously, but instead began in the southern peninsula, where incidence rates had been highest. In May 1965, 386,000 people began treatment in this region, and 512,000 people in the central and northern areas begin receiving drugs in July of the same year. Additional areas were added as evidence of transmission was observed, eventually reaching a peak of nearly 2 million people in 1966.[54] Participation remained consistently high, with over 90% of the population included. Some adverse events were reported during early rounds, but these were not considered to constitute a major problem.[43]

Results of the drug campaign, depicted in Figure 5, were considered to be a great success.

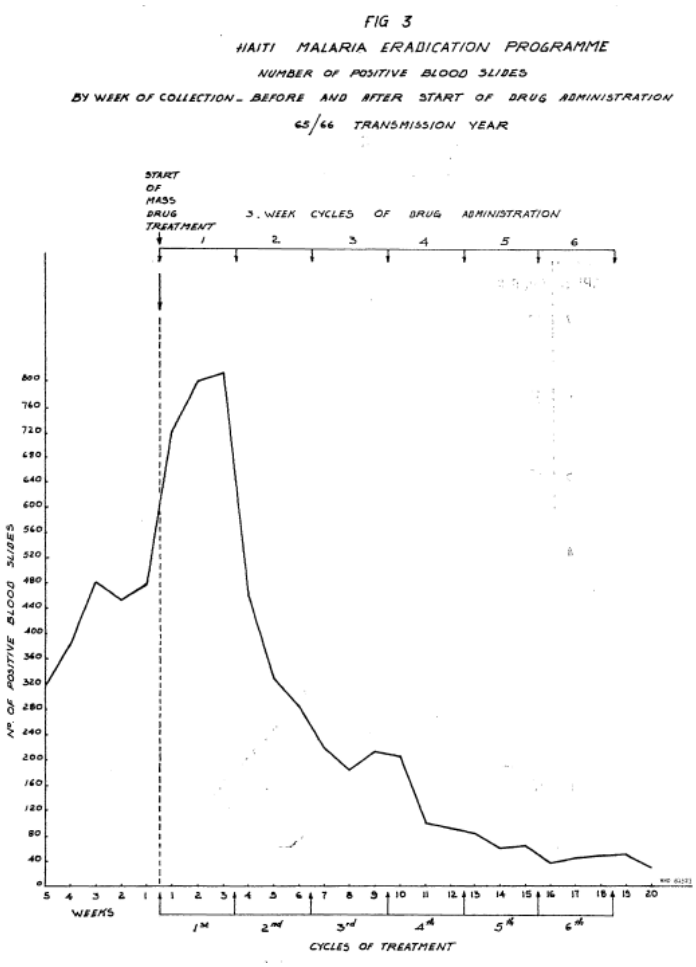


Figure 5. Reductions in malaria incidence in Haiti during 20 weeks of mass drug administration during 1965-66.[43]

In 1966, the Haitian program appeared well on the way to achieving the goal of elimination. That year, 760,000 houses were sprayed with DDT, the homes of approximately 3 million people were reportedly visited by active case detectors on a monthly basis, and well over a million people received anti-malarial drugs. The program's budget reached over US$ 2.5 million,[54] or approximately US$17.5 million in 2012 dollars, though the great majority was contributed by donors. By June, the slide positivity rate had reached a new low of 0.1%. Yet problems loomed. USAID expenditure, which comprised the great majority of Haiti's budget, declined to US$ 1.7 million in 1967 and only US$ 790,000 in 1968.[54] To maximize the reach of the budget, drugs were administered on a region-by-region basis. In each region, administration was conducted throughout the transmission season and for a few months thereafter until transmission appeared interrupted, at which point it was halted and begun elsewhere.[43] A later USAID evaluation highlighted the weakness of this approach:

The drug program was carried out on a large scale but coverage was not simultaneous. While some rural sections were submitted to [mass drug distribution] others were not and vice versa. Consequently the treated Sections Rurales which had become free of malaria were re-infected by carriers coming from untreated areas. Moreover, the drug acceptance rate decreased to the point where it became ineffective.[38]

For example, in the pilot site of Petit-Goave, drug distribution was halted in September 1965 after 15 rounds since it was believed that transmission had been interrupted.[43] It was assumed that door-to-door fever screening measures would be sufficient to identify and treat any residual cases before transmission could be reestablished. However, this supposition proved overly optimistic: at least in part because of reintroduction of cases from neighboring areas, transmission was observed to begin again only a month after cessation of treatment. Drug distribution was restarted at the end of 1965 and continued for another year and a half.

Outbreaks occurred in 1966 following hurricanes and heavy rainfall, including in several regions that were located above 500 meters and had thus been left out of the drug administration campaign. Surveys were conducted throughout the mountainous regions, revealing to the program's surprise that transmission at higher altitude was apparently more common than generally believed, at least in that year.[43] Reports from these surveys could not be identified, however, and reports from other decades continue to refer to malaria as almost entirely occurring below 500 meters.

The program of drug administration and DDT spraying continued throughout 1967 and 1968, though spray coverage was incomplete.[38] Marginal gains and frequent reoccurrences of malaria were seen in areas that had previously received drug administration. A 1968 report by a team of PAHO and UNICEF evaluators concluded that the program should return to a DDT-focused attack and reserve the use of drugs for the highest transmission foci. The report suggested that a predominately drug-focused campaign was unworkable in light of that the population was extremely mobile (meaning that malaria was continually reintroduced into places where the parasite reservoir had previously been drained) and acceptance of the repeated drug administrations had plummeted to only about 35%.[38] Additionally, it was found that *P. falciparum* had developed resistance to pyrimethamine, although chloroquine continued to be effective. The evaluators suggested that source reduction, including potentially draining lakes near Petit-Goave, could also be a useful tool. The return to an elimination program focused primarily on DDT spraying was followed by an increase in malaria incidence from 2,571 cases in 1968 to 5,005 in 1969, 10,658 in 1970, and 11,346 in 1971.

The shift back to methods deemed unlikely to lead to elimination reflected a global movement away from "eradication" towards a less ambitious focus on "controlling" malaria as a disease of public health

importance.[57] The more limited resources available for 1970 from USAID were deemed insufficient for a classical "eradication" campaign, so an emphasis was instead placed upon trying to maintain gains rather than eliminate malaria altogether. IRS was concentrated on high risk areas, leaving low endemic places with no intervention.

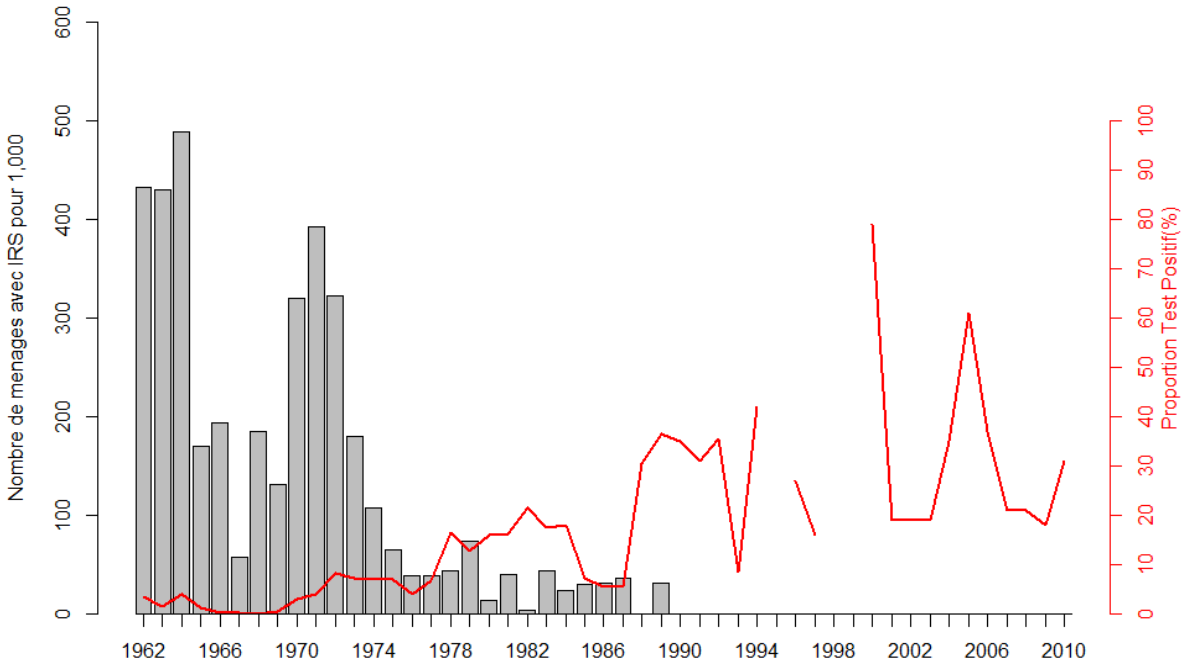


Figure 6. Reductions in the number of households receiving IRS per capita in Haiti and concurrent increases in the slide positivity rate.

Reported malaria cases grew steadily after 1968, when incidence reached an all-time low of 0.56 cases per 1,000. Ten years later, that rate had increased to over 11 per 1,000, with a total of 60,000 cases reported. In 1984 an evaluation team estimated the actual number of cases of malaria at 250,000-300,000 per year and the number of deaths at no fewer than 3,000 per year.[38] SNEM was dismantled in 1988.

No active measures were conducted against malaria until 2003, when Haiti received a US$ 12.8 million grant from the GFATM to Fight AIDS, Tuberculosis and Malaria. The National Program for the Control of Malaria and lymphatic filariasis was formed to distribute insecticide-treated nets, conduct behavioral change communication, and improve diagnosis and treatment of malaria at health facilities.

Overview of the current response on Hispaniola

The island of Hispaniola reported 33,664 *P. falciparum* presumed and confirmed malaria cases in 2011 with 4.8% in the Dominican Republic and 95.2% in Haiti.[58] In the Dominican Republic, approximately a third of cases are found amongst Haitian visitors to the country and 14% amongst Haitians living in the Dominican Republic in 2012. While malaria is considered to be one of the top ten causes of deaths in Haiti, there were only 10 malaria-attributed deaths in the Dominican Republic in 2010.[58]

DOMINICAN REPUBLIC

Epidemiological Situation

In 2012, 952 malaria cases were reported, the lowest number since 1997. The slide positivity rate was 0.23%.[59] All cases were reported as *P. falciparum* malaria. Malaria in the Dominican Republic is most concentrated in poor and vulnerable populations, such as *bateyes* - company towns where sugar workers live - and poor rural locales in 14 municipalities that contribute 71% of cases. The Dajabón province on the border of Haiti accounts for 32% of the country's burden of disease, and the municipality had the highest API with 19 cases per 1,000 inhabitants at risk in 2012. Again illustrating the importance of importation, children under 5 represent only 4.5% of all cases while the demographic most affected is males between 19 and 29, who represent nearly 20% of cases.

Program Overview

CENCET coordinates a response funded by the government, GFATM, CDC, and PAHO. The GFATM grant is the primary source of funding and covers 14 priority districts in five provinces, most of which are near the border with Haiti. This area has an estimated at-risk population of 514,000 people. CENCET and Instituto Dermatologico y Cirugia de Piel (IDCP) are the co-Principal Recipients of the grant. IDCP is a non-governmental agency responsible for coordinating all social mobilization activities for the grant, including mosquito net distribution. With 30 people at CENCET and 12 at IDCP for managing the GFATM grant, the two agencies have managed a robust response, aided by two sub-recipients of the GFATM grant, one working with Haitian migrants and the other with Dominican nationals. Approximately 80% of the malaria funding comes from the government.

Malaria Strategy

The National Malaria Strategy focuses on the need to ensure timely case detection and effective case management, surveillance, vector control, and community mobilization. Samples are sent to one of three reference laboratories for confirmation. Beginning in 2000, the DR tested all suspected cases with microscopy.

Additional case detection is conducted though active surveillance amongst high-risk groups. The national strategy specifies the need for this work amongst agricultural and construction workers. In practice, this is implemented by volunteers through door-to-door active case detection in endemic locations and at the border, using rapid diagnostic tests (RDTs).

Reference laboratories report cases to CENCET weekly through fax. The program is currently working on automating this system. Case-level data is entered into the central-level database managed by CENCET, which disseminates data regularly through the Internet and presentations to government and non-governmental stakeholders. For example, regular updates to IDCP ensure that they are able to reorient their social mobilization activities to changing hotspots.

Community health workers follow-up all cases, implementing directly observed therapy (DOTS) over the three-day course of medications (1 day of Primaquine, 3 days of Chloroquine). These volunteers are generally community leaders recommended to CENCET that have already done work in community health. The testing and treatment norms have been regularly updated and doctors, nurses, and lab technicians receive regular refresher trainings as well as an accompanying practitioner manual.

In addition to case detection and management, the strategy places a strong emphasis on prevention. This includes vector control and specifically larviciding, fumigation, and mosquito nets. The vector control norms are currently in revision. However, in past norms, aerial fumigation has been recommended for the general context, larvicide for areas of malaria outbreaks, and LLINs for highly vulnerable populations. The GFATM grant provides for one central and eight provincial entomology teams, each including one entomologist and one auxiliary. These teams manage larval breeding sites in priority districts, providing geo-referencing, quantifying larval densities and applying control solutions. In addition, they conduct operational research on IRS, LLIN, and insecticide efficacy.

Community participation is highlighted in the National Strategy as contributing to the success of each of the interventions mentioned above. According to a recent survey on knowledge, attitudes, and practices, knowledge and behavior around malaria prevention and treatment are high, with 84% of the population knowing that they should go to the hospital if they have a fever and 65% understanding the risk of malaria. In addition to this risk perception and treatment seeking behavior, the population is receptive to giving blood samples.

IDCP has 20 health promoters and hundreds of volunteers dedicated to communication. The distribution of flyers and brochures has reached an estimated 75,000 households. In addition, volunteers conduct promotional activities at mass events and medical experts participate in discussion sessions on public radio. There is a national communication plan that describes who should be targeted and with what medium, as well as promoter manuals for the volunteers.

Table 2. Summary of the current response.

Summary of the Current Response	
Strengths	**Weaknesses**
• Testing of all suspected cases • Case-level reporting to the central level • Active case detection in high-risk areas and amongst high risk groups • Directly observed therapy • Targeted vector control efforts • High level of community understanding and participation in the response	• Limited funding for low- to medium-risk areas • The passive surveillance system is not yet automated • Reliance on microscopy for diagnosis
Opportunities	**Threats**
• Interest and political commitment for increased collaboration with Haiti • A new CDC project implementing a response on the border of Haiti and the DR	• Illegal migration from Haiti • Hurricanes and other unpredictable events • Lack of donor funding beyond the current GFATM grant

HAITI

Epidemiological Situation

Variable testing and reporting at health facilities cast uncertainty on national estimates of malaria incidence; 135,136 suspected cases were reported in 2011, of which 32,048 were confirmed.[58] National health facility positivity surveys conducted in 1995, 2005, and 2007 found slide positivity rates of 4%,

3.5%, and 4.9%, respectively.[60] A recent population-based survey conducted by PSI in 2011 detected a population parasite prevalence of 0.9%;[61] a more focal study in the Artibonite Valley found a prevalence of 3.1% in 2006.[62]

Clinical resistance to chloroquine is a well-studied topic in Haiti. Researchers found evidence of genetic resistance in *P. falciparum* in the Artibonite region in 2007.[63] Between 2007 and 2009, however, only 2 of 901 samples from 15 sites were found to have resistant phenotypes by the national surveillance network.[a] The investigators of these studies emphasized the importance of immediate elimination to avoid the development of clinical resistance.

Program Overview

The National Malaria and Lymphatic Filariasis Control Program at the Ministry of Health (CPNMFL) is situated within the Unit for the Coordination of HIV, TB, and Malaria/LF Programs (UCP). The program has 23 dedicated personnel, of which 9 are programmatic, working in M&E, communication, vector control, and general program management.

The Ministry of Health has a departmental directorate (DDS) in each of the ten departments of the country. Each department has an M&E officer in malaria who reports directly to the UADS (Unite d'Appui a la Decentralisation Sanitaire) in the MSPP, and in the case of malaria, reports indirectly to the CPNMFL. Three departments have a vector control team or "brigade," with two additional central teams near Port-au-Prince. Each team is made up of five members.

In addition to the program, other MSPP directorates which do not report to the CPNMFL, play a key role in malaria control. Some of the most critical include the National Laboratory (LNSP) and the directorates for epidemiology and laboratory research (DELR), pharmaceuticals and traditional medicine (DPM/MT), organization of services (DOSS), and health promotion (DPSPE). While other ministries such as the Ministry of Agriculture, Ministry of Environment, and Ministry of Youth and Sports, are mentioned in the National Strategic Plan, they are not engaged in the current response.

The primary source of funding for malaria work is the GFATM, for which the CPNMFL is one of eight sub-recipients of the GFATM grant, and PSI is the principal recipient. The other sub-recipients of the GFATM include eight local NGOs, each managing sites that conduct malaria testing and treatment or running behavior change communication programs. Approximately 20% of the malaria funding comes from the Haitian government.

In addition to the GFATM, the program receives funding for malaria through CDC and PAHO/WHO, as well as support for bi-national efforts from the Carter Center. The University of Notre Dame, the Bill & Melinda Gates Foundation, and the CDC provide support for LF activities.

Malaria Strategy

The current malaria program has three main arms: passive case detection and treatment, follow-up of the mass net distribution campaign and fumigation, and BCC.

The CPNFML provides guidance to stakeholders through communication in meetings, as well as documents such as the National Strategic Plan, revised in 2013 by the Program which aims to eliminate malaria by 2020 through a few key objectives including reinforcing M&E and surveillance, care and treatment, and effective prevention and communication.

[a] Amplification of the pfcrt was conducted. The two samples were found by Cornell University in the 158 tested at their facilities. Interview with GHESKIO.

Current surveillance is largely limited to passive case detection and passive health information systems, and not all suspected cases are confirmed by diagnostics. The program is also using sentinel surveillance sites and population-based surveys to determine more accurate parasite prevalence. However, there is little active surveillance in the country (CDC is supporting active surveillance in sentinel sites). Monitoring and evaluation of the response is limited to what is required as part of the GFATM grant or from other donors.

RDTs were adopted in 2010, and in 2011, the care and treatment norms were revised to include chloroquine-primaquine bi-therapy as first line treatment. By 2015, the country plans to scale-up RDTs to all health facilities that lack microscopy capacity. Primaquine has been available in country since the fall of 2012, although a much wider training of clinicians on the new norms will be critical to drive uptake.[b] While directly observed therapy (DOTs) is not conducted, doctors are meant to observe patients taking the first dose at the clinic.

In terms of prevention, noting a very low level of bednet usage in the country, PSI executed a mass distribution of nearly two million LLINs targeting 80% of households (Figure 7), based on population census data.

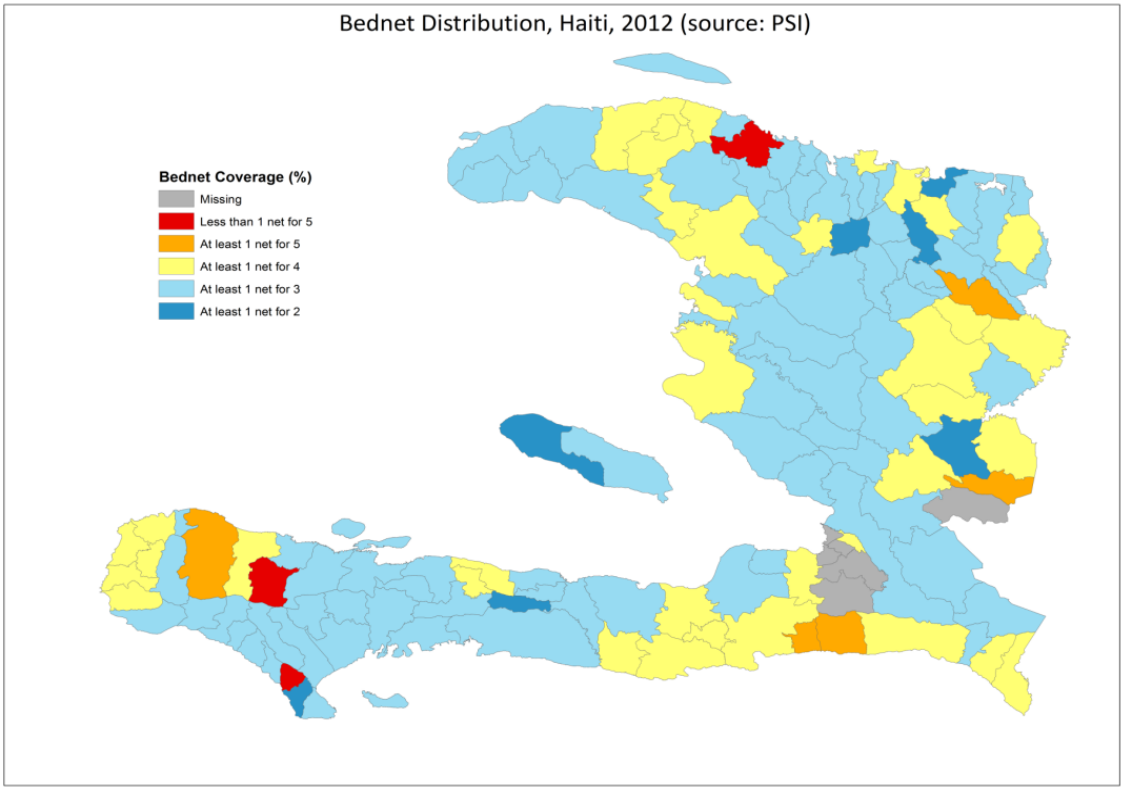


Figure 7. Estimated coverage achieved during the 2012 bed net distribution based on the number of nets distributed per population.

[b] The norms also mention second-line antimalarials though these are by definition rarely used unless the patient shows intolerance, potential treatment failure, or Chloroquine is not available. These second-line medications include Sulfadoxine-Pyrimethamine, mefloquine, or ACTs.
MSPP (2011)

The efficacy of this intervention given vector behavior is currently being assessed. Additional vector control measures are limited for the most part to *ad hoc* source reduction and larviciding, although will increase over the next year with the increase in the number of equipped brigades.

Community health workers are involved in some vector control efforts and play a pivotal role in communication activities. Each sub-recipient of the GF grant is responsible for conducting such activities in their catchment areas. The program has a communication plan which provides some guidance to sub-recipients in the implementation of these activities. All communications are approved by the CPNMFL.

Despite tremendous strides in recent years, the program realizes that additional investment is required to achieve elimination. The strengths and improvement areas of the national response will be further explored in the operational feasibility assessment.

BI-NATIONAL RESPONSE

After the ITFDE first recommended elimination of LF and Malaria, the Carter Center encouraged collaboration on an operational level, through funding an 18-month long demonstration project in two adjacent communities on the border of Haiti and the Dominican Republic (Dajabón and Ouanaminthe) in 2008. The program included health education, free malaria diagnosis and treatment provided through DOTS by community health workers, epidemiological surveillance, and vector control using IRS and LLINs. Lessons learned in the Dominican Republic were meant to be shared with Haiti. The project had demonstrably successful results and recently, CDC has re-launched the project. The community health workers (CHWs) under the CDC project are currently being trained to use RDTs to facilitate community-based screening.

These operational projects are accompanied by political efforts as the two governments recognize the importance of collaboration in achieving elimination. In 2009, the Carter Center and the two Ministries of Health launched a joint Dominican Republic-Haiti initiative that announced a bi-national strategic plan for the elimination of malaria by 2020, which proposed a budget of US$194 million to achieve elimination. The Carter Center continues to sponsor quarterly meetings between the two governments, which, at the time of this report, are being used to update the bi-national plan, though this process has been delayed multiple times. At a local level, the GFATM grant has also required border commune level meetings where bi-national agreements have been signed. The national government and these communes recognize that coordinated implementation and data sharing are essential at both the national and local level.

Table 3. Summary of the current response.

Summary of the Current Response	
Strengths	**Weaknesses**
• Recent adoption of RDTs and Chloroquine+Primaquine • Entomological studies and larviciding conducted as needed • Involvement of CHWs in the response	• Lack of training and dissemination of the most recent norms and National Strategic Plan • Reporting of suspected, rather than confirmed cases • Incomplete case reporting and lack of mechanism to send information on individual cases to the central level • No active case detection • Little to no dissemination of information, preventing the targeting of key interventions
Opportunities	**Threats**
• Interest and political commitment for increased collaboration with the DR • Expansion of the Ouanaminthe-Dajabon community testing model of the MSPP/CDC project • Success of the LF campaign in 2012 using grassroots workers indicates the potential for mobilization around elimination • Similar efforts to improve surveillance in cholera	• Unpredictable events such as natural disasters cause instability, migration, and increased malaria transmission • Lack of funding for all requests made in the GFATM grant

TECHNICAL FEASIBILITY

The objectives of the technical feasibility assessment were to:

1. Describe the epidemiology of malaria in Haiti in space and time using the currently available data
2. Identify low and high risk areas of transmission in the country, and quantify the population living in each
3. Assess the impact of interventions to reach elimination, and considering both vector control and parasite-based approaches at different levels of coverage
4. Estimate the time to reach elimination
5. Understand the magnitude of malaria parasite movement on the island and its implications for the elimination effort
6. Understand the risk of malaria resurgence after elimination and what will be required technically to avoid it

Epidemiology of malaria in Haiti in time and space

There are two national surveillance systems recording malaria cases. Cases of malaria identified in approximately 800 health facilities across Haiti are recorded into a health management information system named HSIS (Haïti Système d'Information Sanitaire). The digital version of the system was implemented in 2006, and records are available from when it became operational in 2007. Several indicators disaggregated by age and gender are collected each month in each participating facilities: number of confirmed malaria cases, number of hospitalized cases (see Table 4 for details). The following case definitions are used:

- Suspected case: patient with fever not diagnosed with blood test but treated with chloroquine
- Confirmed case: suspected case positive for malaria according to blood test

The creation of another system named NSSS (National Sentinel Site Surveillance System) was supported by the CDC in 2010 to fill some gaps of HSIS regarding malaria case definitions. Fewer health facilities are currently participating (n=107), and in each facility, epidemiological surveillance officers record cases according to the following definition:

- Suspected case: patient with fever >38C (currently or in the last 48 hours) associated or not with other symptoms such as nausea, vomiting, diarrhea, headache, pain, rigors, myalgia, and for which other obvious causes of fever were excluded.
- Confirmed case: confirmation of the presence of malaria parasite using RDT or microscopy.

Table 4. Comparison of the HSIS and NSSS surveillance datasets.

System	HSIS	NSSS
Description, and purpose	The health information system created for surveillance and monitoring of the quality of services.	A surveillance system created to monitor infectious disease.
Management	Managed by the Unit for Planning and Evaluation (UPE) and the Directorate of Epidemiology and	Managed by the Directorate on Epidemiology and Laboratory Research (DELR) of the MSPP.

	Laboratory Research (DELR) of the MSPP.	
Structure of the network	Approximately 800 public, private, and mixed institutions are registered and report?	107 public and mixed institutions are registered and report.
Indicators	Reporting is monthly and includes the following malaria indicators: *Amount of tablets of chloroquine distributed;* *Number of malaria tests used?;* *Number of cases receiving chloroquine;* *Number of confirmed cases;* *Number of resistant cases (coming back to facility after initial treatment); and* *Number of hospitalized cases.*	Reporting is weekly and includes the following indicators related to malaria: *Suspected cases of malaria; and* *Laboratory confirmed cases of malaria*
Data flow	The report is delivered to the departmental office, where the statistician or data clerk enter the data into the HSIS database. This information is then automatically accessible to the Director General, UPE, and the DELR.	Information is transferred by site personnel to the central level (the DELR or LNSP) via text, calls, email, or hand delivery. In the case that data is not received on time, a member of the DELR or LNSP contacts the site.

HSIS data were used to examine the epidemiological situation in Haiti. From 2007 to 2012 the number of malaria cases reported each year varied between approximately 15,000 and 30,000 with a peak in 2010 at 32,972. Lowest figures were reported in 2007 at 12,766, which may be due to an underreporting of cases as the system had just started the year before. There was no apparent temporal trend in the number of cases, and on average 24,040 cases were reported each year during the 6-year period (Figure 8a).

The monthly number of reported cases averaged over 2007-12 decreased between January and December from 2,705 to 1,168. The monthly numbers remained stable from January to June with approximately 2,300 cases each month before decreasing from July onwards (Figure 8b). Malaria is seasonal in Haiti with a rainy season from November to January and then from May to July. The observed pattern did not align with rainy seasons as expected, perhaps due to issues in either treatment seeking, testing at health facilities, or reporting to the HSIS database.

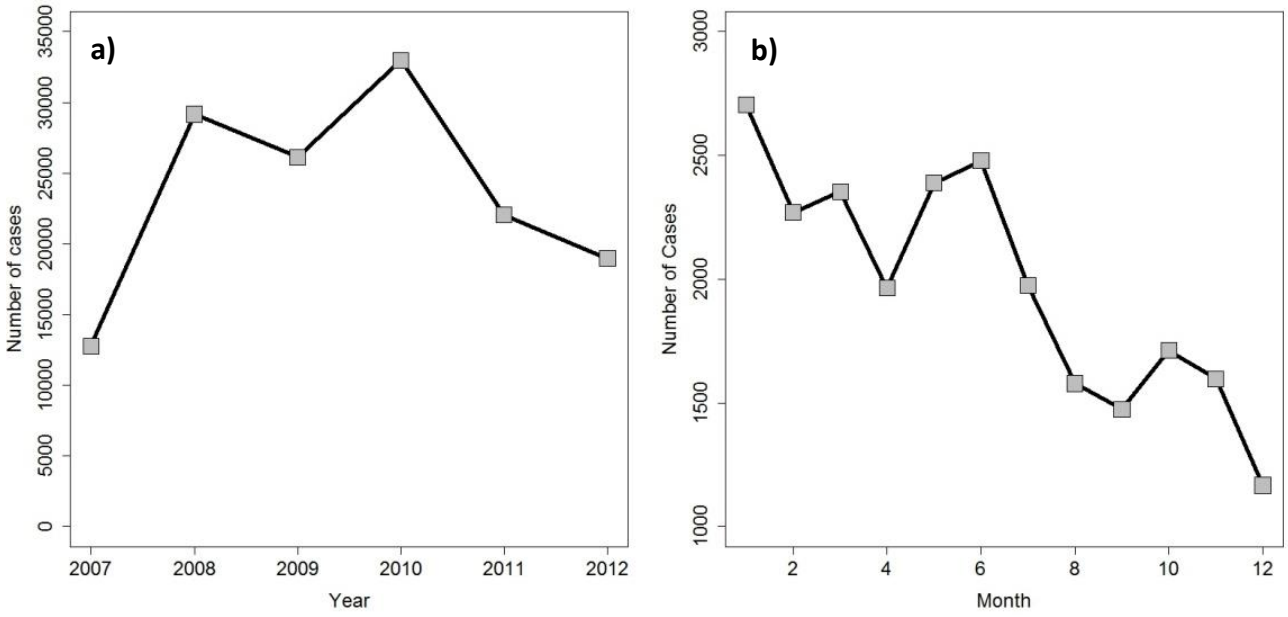


Figure 8. Total number of confirmed malaria cases reported to HSIS a) each year between 2007 and 2012, b) each month averaged over the period 2007-2012.

Over 2007-12, highest annual incidence in the HSIS were observed in the Centre, Grande Anse, and Nord region, which accounted for 23%, 9%, and 11% of all malaria cases in the country, respectively. The regions accounting for most cases were Ouest (24%), Centre (23%), and Artibonite (16%).

Table 5. Number of confirmed cases by region in the HSIS dataset, 2007-12.

Region	Confirmed cases (per 100,000)	Number of confirmed cases (% of total)
Centre	767	5,460 (22.7)
Grand Anse	501	2,240 (9.3)
Nord	257	2,620 (10.9)
Artibonite	240	3,953 (16.4)
Nord-Est	210	789 (3.3)
Sud	196	1,449 (6)
Nippes	167	547 (2.3)
Ouest	149	5,724 (23.8)
Nord-Ouest	123	852 (3.5)
Sud-Est	67	406 (1.7)

Figure 9 shows annual malaria incidence by commune from 2007 to 2012. Each year approximately 15% to 20% of the communes have no cases reported either because there were no cases or because the communes failed to report; communes not reporting differed from one year to the next. Cases were reported in various parts of the country with no apparent spatial pattern; some communes reported high incidence in a given year, mainly in the southwest and northeast of the country, but this pattern did not appear consistent over the studied period.

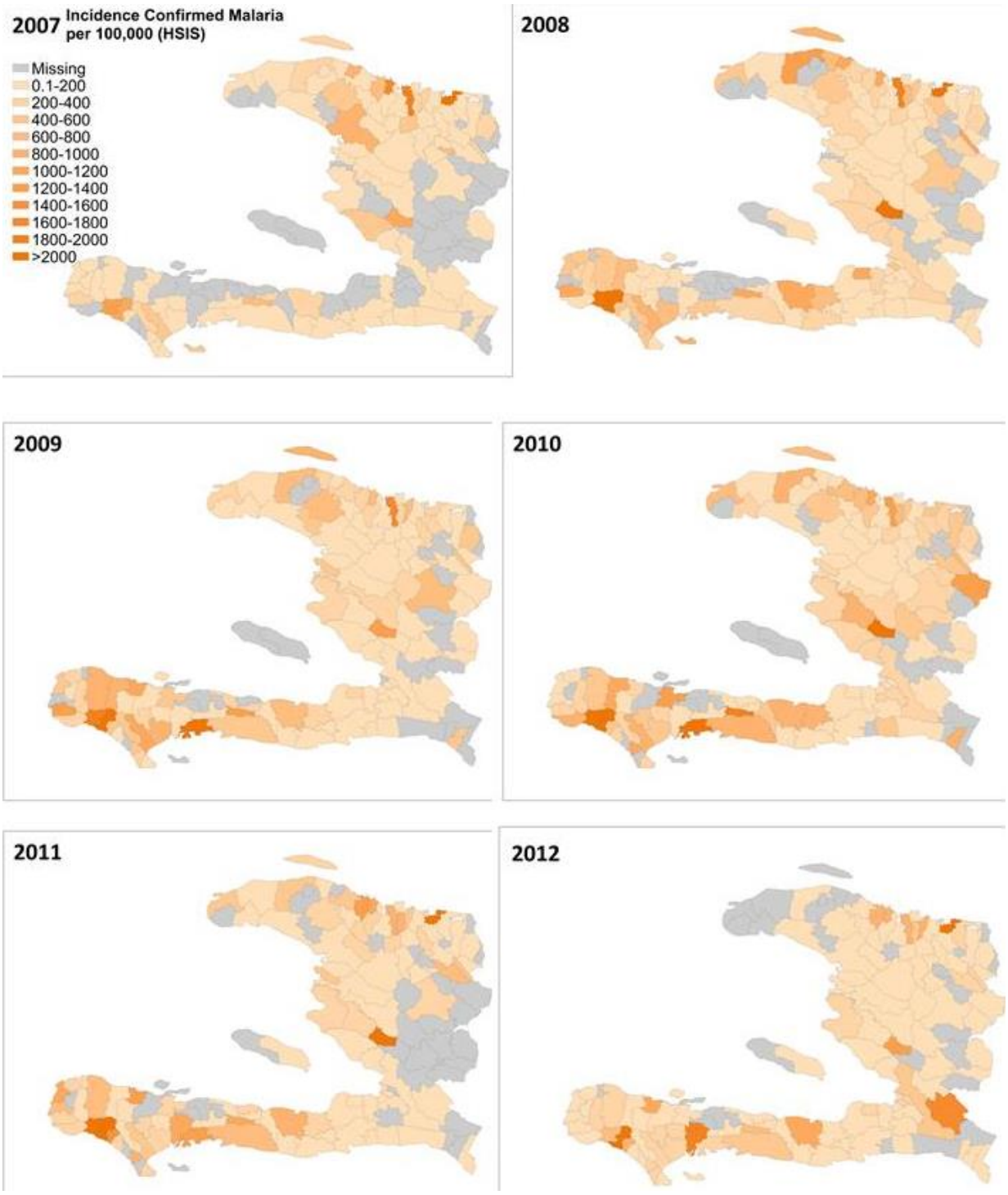


Figure 9. Annual incidence of confirmed malaria cases per 100,000 from 2007 to 2012 by commune according to the HSIS database.

Where is malaria in Haiti?

Malaria is known to be heterogeneously distributed in consistent foci or "hot-spots",[50] but this spatial variation was not captured by the incidence maps based on HSIS data. The inconsistent distribution of cases in the HSIS data from year to year may occur due to reporting bias in HSIS linked to access to healthcare, diagnosis practices, or transmission of the epidemiological information. In order to reach elimination, there is a need to better identify where malaria transmission actually happens at a high spatial resolution.

To accurately understand where transmission is occurring, each confirmed case of malaria diagnosed in health facilities should be investigated and geo-coordinates collected on the likely locations of transmission, such as the cases' household. Information on case household locations can be used to identify spatial risk of malaria but was not available at the time of this assessment. Instead, test positivity rates (TPR, or the proportion of confirmed cases through microscopy or RDTs among all tested cases) collected in NSSS health facilities in 2011 were used as an epidemiological indicator, and a proxy for malaria risk. In using the test positivity rate, we assume that healthcare workers in the NSSS facilities tested all suspected malaria cases per the stated protocol for NSSS sites. While this assumption may not hold true, it is unlikely to substantially bias this analysis unless variable testing rates from facility to facility manifest specific spatial patterning. Under this assumption, higher positivity rates were found in health facilities located close to the coast mainly in the south and north of the country. TPRs were low to medium in and around Port-au-Prince, and low in the center of the country (Figure 10).

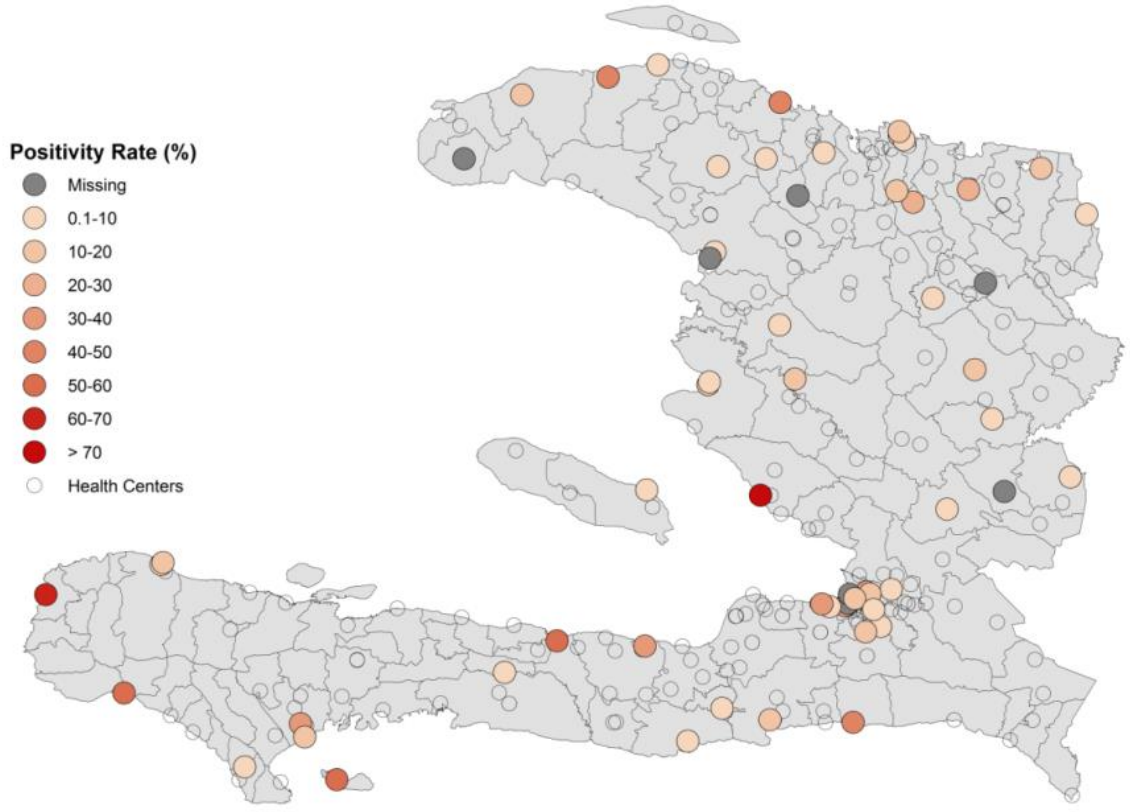


Figure 10. Proportion of cases tested positive (RDT or microscopy) among all suspected cases at health facilities part of NSSS network in 2011 (n=62). The black transparent circles correspond to the health facilities not part of NSSS (n=754).

We used spatial logistic regression to extrapolate from these health facility locations to all points across Haiti, producing a risk map with an estimated positivity rate at 100 meter resolution. The proportion of confirmed cases among all suspected cases reported in NSSS health facilities in 2011 was modeled as a function of a set of socio-demographic and ecological variables (Figure 11): population density (www.ameripop.org), nighttime light (a proxy for urbanization), land cover, Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Topographic Wetness Index (TWI), distance to rivers, and elevation (which is correlated to temperature and precipitation). The value of each of these covariates was extracted for the location of each of the NSSS health facilities, and logistic regression models that adjusted for spatial correlation were fit to predict the positivity rate as a function of these variables.

Results indicated that positivity rates were significantly higher at locations of lower elevation, closer to rivers, at lower population density, with lower NDVI values, higher NDWI values, and lower topographic wetness; land cover type was also associated with the positivity rate. The logistic regression model that resulted was used to extrapolate positivity values across all of Haiti. These values – which refer to test positivity rates at the locations of health facilities – are not readily interpreted as measures of transmission, but they show expected relative heterogeneity in malaria across the country and are thus useful for demonstrating where malaria transmission can be expected to be higher or lower.

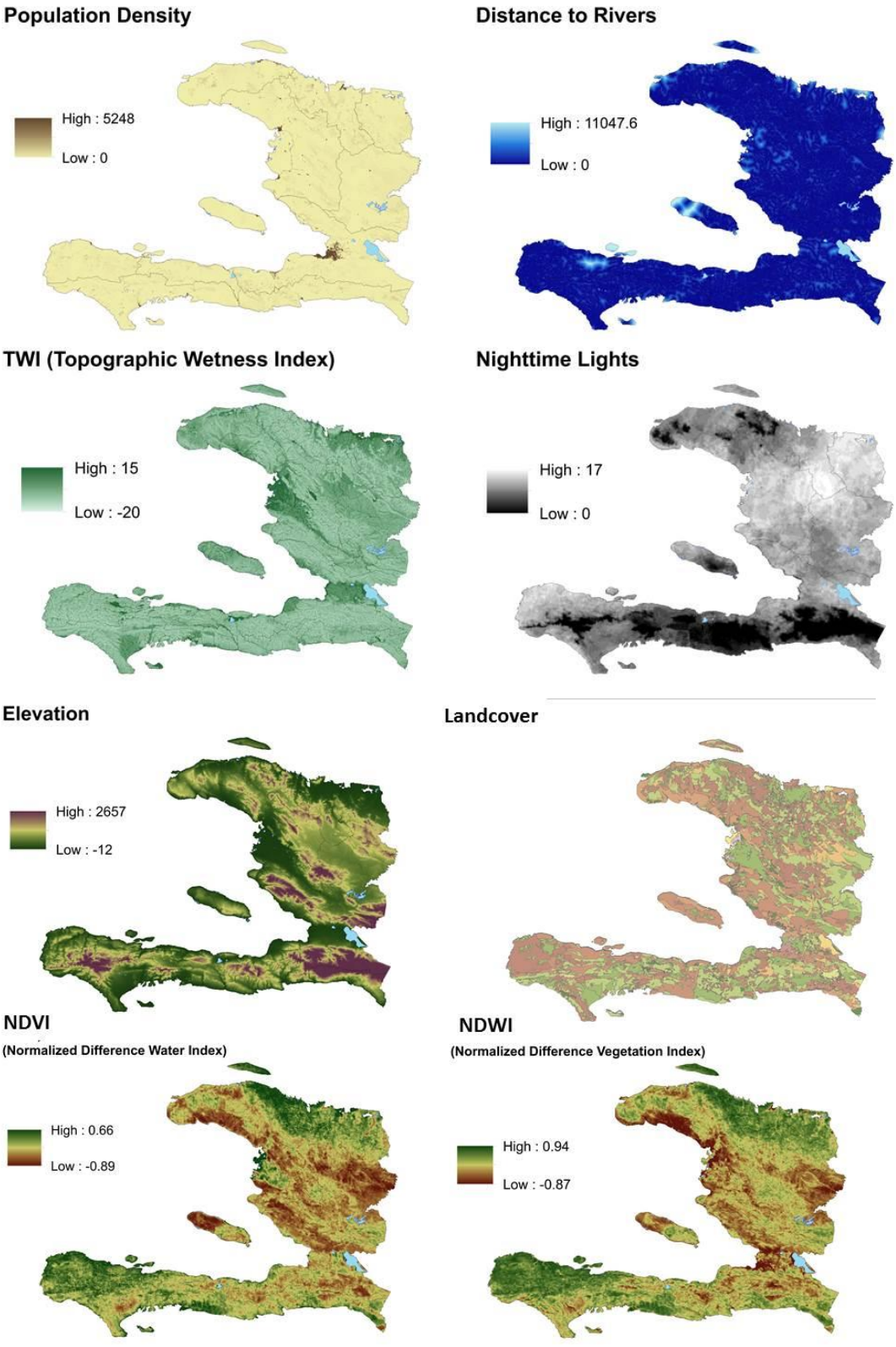


Figure 11. Spatial covariates used to model malaria across Haiti.

The resulting map of predicted risk is depicted in Figure 12. As expected, it shows a high degree of variation in malaria risk. Higher risk of malaria was found along the coasts, especially in the North-East and South of the country, along the Artibonite valley, and east of Port-au-Prince. This distribution makes sense in light of observations that *An. albimanus*, the principal vector in Haiti, is frequently found breeding in brackish water along the coast.[33] There was no to low risk in most areas in the center of the country, which tend to be at higher elevation and thus in places less suitable for *An. albimanus*. This map suggests that there are specific places in Haiti where interventions should be targeted to have the greatest effect on malaria transmission.

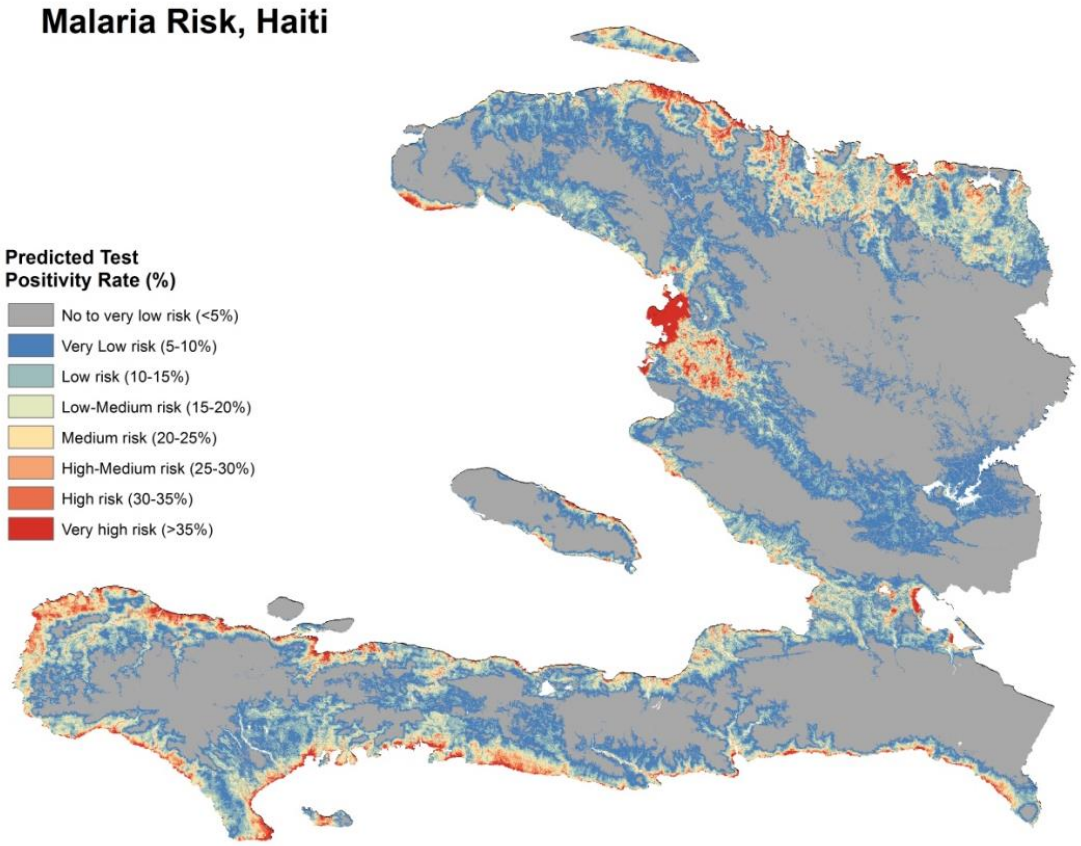


Figure 12. Predicted malaria risk in Haiti (based on NSSS data from 2011 and a set of ecological and socio-demographic variables)

This map has important limitations that must be considered, particularly in terms of the quality of the input data related to malaria. First, test positivity rates are potentially a biased indicator which may vary according to testing practices. As such this indicator may not accurately represent the risk of malaria. For example, health facilities testing only severe fever cases may experience higher positivity than facilities testing everybody. Nevertheless, data were collected in facilities part of the sentinel network (NSSS) where epidemiological surveillance officer are trained to follow standardized case definitions, and all suspected cases are supposed to be tested. Any potential bias should be non-differential and test positivity rates should be largely comparable across health facilities. In addition, values for the epidemiological, ecological, and socio-demographic covariates from which the map was generated were extracted at the location of the health facility. Doing so is equivalent to assuming that the health facility

location corresponds to where malaria transmission happened. In reality, transmission happens during outdoor evening activities or while sleeping (i.e., at the locations of patients' households); if patients live near health facilities, the error introduced by this assumption may be small, but if catchment areas are broad, it could be substantial. The identified risk areas appear in agreement with expert opinions, but as per the caveats mentioned above, refining this map using high quality surveillance data, such as case household location collected through the passive or active national surveillance or during epidemiological surveys.

POPULATION AT RISK

The country was stratified into four risk categories based on the results of the predicted risk map: negligible risk (predicted TPR below 5%), low (TPR between 5 and 15%), medium (TPR between 15 and 30%), and high risk (TPR above 30%). These zones were applied to a map of population density[64] to estimate the number of people living within each zone. In addition, to estimate a more operationally meaningful metric for each TRP zone, mean population-weighted TRP within each zone was converted into approximate population prevalence, assuming a national prevalence of around 1%.[61]

Approximately one-third of the population (31%) is estimated to live in places where there is no or negligible risk of malaria; 45% live in low risk places with an estimated PR of 0.3%; 20% in medium risk places with an estimated PR of 2%, and 3% of the population live in high risk areas with an estimated PR of 15% (Table 6). The number of infections was estimated at approximately 175,000 per year assuming malaria infections last for 200 days on average. Only a small proportion of infections will be seen in health facilities and reported to the national health system (HSIS). Some infections may be asymptomatic, and some symptomatic individuals may not seek healthcare (see operational section for further details). These results will vary according to the cut-off values used to classify malaria risk at the country level, but they suggest approximately one quarter of the Haitian population live in places currently classified as medium and high risk and that should be the primary focus of elimination efforts.

Table 6. Population living in at-risk areas based on predicted positivity rate. Prevalence is distributed according to mean TPR values; disease is assumed to last for 200 days.

Area at risk	Predicted TPR (%)	Mean TPR (%)	Prevalence Rate(%)	Population at risk ('000)	Number of infections/year
Negligible	0-5	2.5	0.05	3013 (31%)	2,736
Low	5-15	9.8	0.3	4347 (45%)	21,882
Medium	15-30	20.4	2.1	1938 (20%)	73,855
High	>30	35.1	14.6	287 (3%)	76,589

Technical strategies for attacking malaria foci

Currently available tools enable two main categories of interventions that can be implemented in identified high risk areas to reduce malaria transmission:

- *Vector control interventions such as larvicides, LLINs, IRS or fumigations*. These strategies target the vector *An. albuminus*. They aim to kill larvae or adult vectors before they transmit the parasite, or prevent bites on human hosts through repellent effects or by providing mechanical protection.

Environmental management such as filling ponds would also have an impact on vector population density.

- *Parasite-based interventions that directly target the parasite in the host by curing infected individuals*. Such strategies generally involve implementing surveillance activities, such as strong passive surveillance coupled with active response, and providing appropriate case management, with effective diagnosis and appropriate treatment.

Mathematical transmission models are simplified representations of the world, but they provide a useful tool for understanding the potential for these tools to influence transmission and testing what combination of interventions will make elimination feasible in Haiti under different scenarios. The potential for Haiti to eliminate malaria in delimited foci was evaluated using stochastic individual-based malaria transmission models developed by Imperial College[65] and Johns Hopkins School of Public Health (unpublished model). The models incorporate a number of complexities that make them more realistic than classical mathematical models which assume that mosquitoes bite all individuals equally, for example[66] (for more specifics of the models see corresponding literature). The model parameters were estimated using Haitian estimates of malaria transmission, and an assumption was made that the malaria vector in Haiti manifests similar behavior to *An. arabiensis*, an African outdoor-biting vector for which the Imperial College model was parameterized. The main output was malaria prevalence rate. There is some variability around any stochastic model output, and each simulation run may provide different PR estimates for the same set of input data. For example, 100 simulation runs with the same input data may provide PR estimates of 0% (elimination) in 60 runs and of 10% in 40 runs; the average simulated PR would be 4% and the probability of successfully eliminating malaria 60%. For simplicity this variability is not provided here, and we instead present the average prevalence rate following 50 runs of the model.

Both models were used to assess the impact of vector control (ITN and IRS) and parasite-focused strategies[67] (passive and active surveillance, and case management) on malaria dynamics.

VECTOR CONTROL IN IDENTIFIED MALARIA FOCI

Bednets were distributed in 2012 all over the country except in 6 communes in and around Port-au-Prince and East. Distribution was otherwise quite homogeneous throughout the country regardless of malaria risk. At least 1 bednet for 3 people was distributed in the majority of the communes, except in eight that had a coverage of less than 1 bednet for 5 people. Field studies are currently being implemented to estimate bednet usage and assess their effectiveness.

Although these trials will be the best measures of the impact of the distributed nets, simulation models can be used to estimate their effects in the short-term. We simulated various vector control interventions to assess their impact on malaria elimination. Simulations showed that vector control alone will probably not lead to malaria elimination. For example, in a foci with an initial prevalence of 10%, distributing bed-nets every 3 years over 10 years at 95% coverage would lead to a 75% reduction in prevalence by year 10, but halting distribution at that point would result in an eventual return of malaria to its initial baseline (Figure 13). This failure to eliminate even at high coverage may be explained by the characteristic of the vector, which bites preferentially during evening when the population may not be protected by nets.

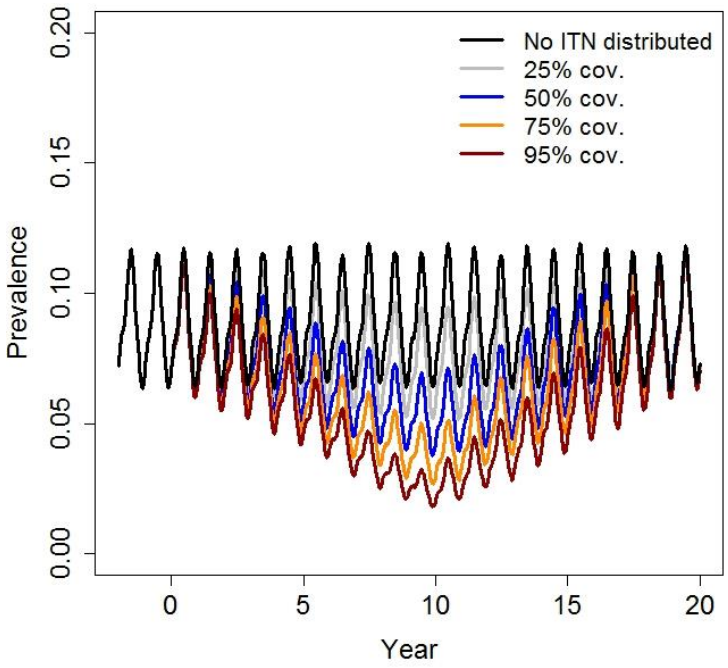


Figure 13. PR over time (years) following the distribution of nets every 3 years during 10 years for various coverage 25% (grey solid line), 50% (blue), 75% (orange), and 95% (dark red). The black solid line represents baseline malaria prevalence in foci (10%)

In addition to assessing the impact of net distribution, we evaluated the impact of IRS on malaria elimination. IRS involves spraying household walls with insecticide, which repels and kills mosquitoes when they rest after feeding on humans. Such strategies were used previously in Haiti during the elimination program of the 1960s, but not currently. We simulated a scenario with IRS at 95% coverage and 1 to 4 rounds a year 1 month apart during low malaria season. The intervention ran for 5 years, and the results are depicted in Figure 14. Although low malaria prevalence is achieved in the simulation, elimination does not result, and malaria returns to its initial baseline after interventions stop in all cases.

These results appear consistent with the actual implementation of IRS in Haiti during the 1960s. Dramatic reductions in malaria incidence were achieved at that time through the use of DDT spraying, but elimination could not be achieved through that intervention alone and malaria eventually resurged once it was stopped. These simulations suggest that vector control strategies alone may again be useful for reducing baseline prevalence (and that the 2012 distribution of nets across the country should have some measureable effect on malaria transmission), but both these results and Haiti's history suggest that vector control efforts are unlikely to eliminate malaria, most likely due to the vector behavior. Complementing vector control with additional strategies targeting the parasite in human hosts will likely be required to achieve elimination.

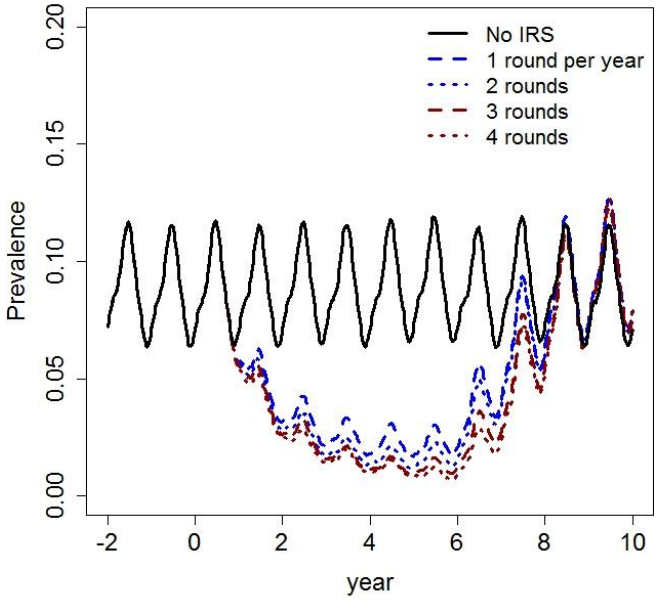


Figure 14. Prevalence rate over time (years) following the implementation of IRS (1 to 4 rounds per year) every year during 5 years at 95% coverage. The black solid line represents baseline malaria prevalence in foci (10%).

PARASITE-FOCUSED INTERVENTIONS IN IDENTIFIED MALARIA FOCI

The objective of this strategy is to clear the parasite from human hosts using anti-malarial drugs while preventing any further transmission. We applied simulation models to assess the fraction of infections that would need to be cured to eliminate malaria. These simulations showed that at least 70% of infections need to be detected and cured in high risk foci with a baseline PR of 15%, assuming a baseline level of treatment of 20%. Below that threshold, increasing the fraction of cured infections would reduce the prevalence of malaria but not achieve elimination. At that threshold rate of 70% of malaria infections being cured, elimination would be achieved within 9.5 years. Increasing the fraction of infections being cured would speed up elimination; for example, at a 90% cure rate, elimination would occur in only 3 years (Figure 15).

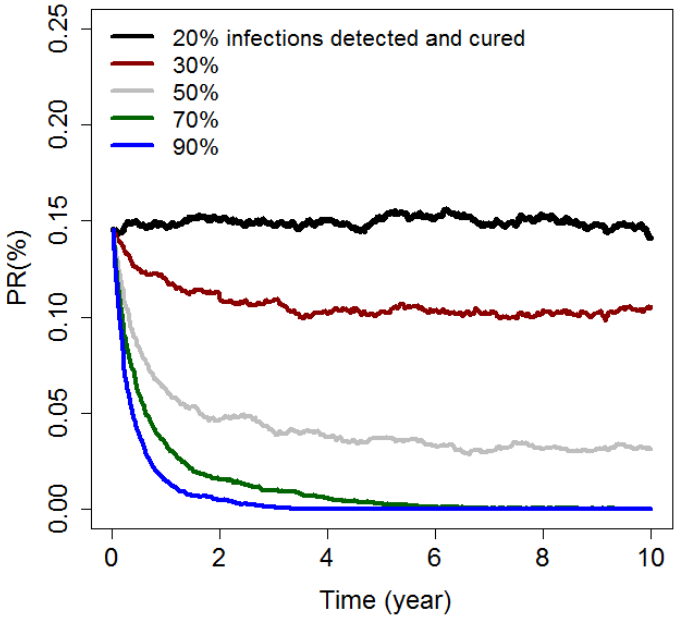
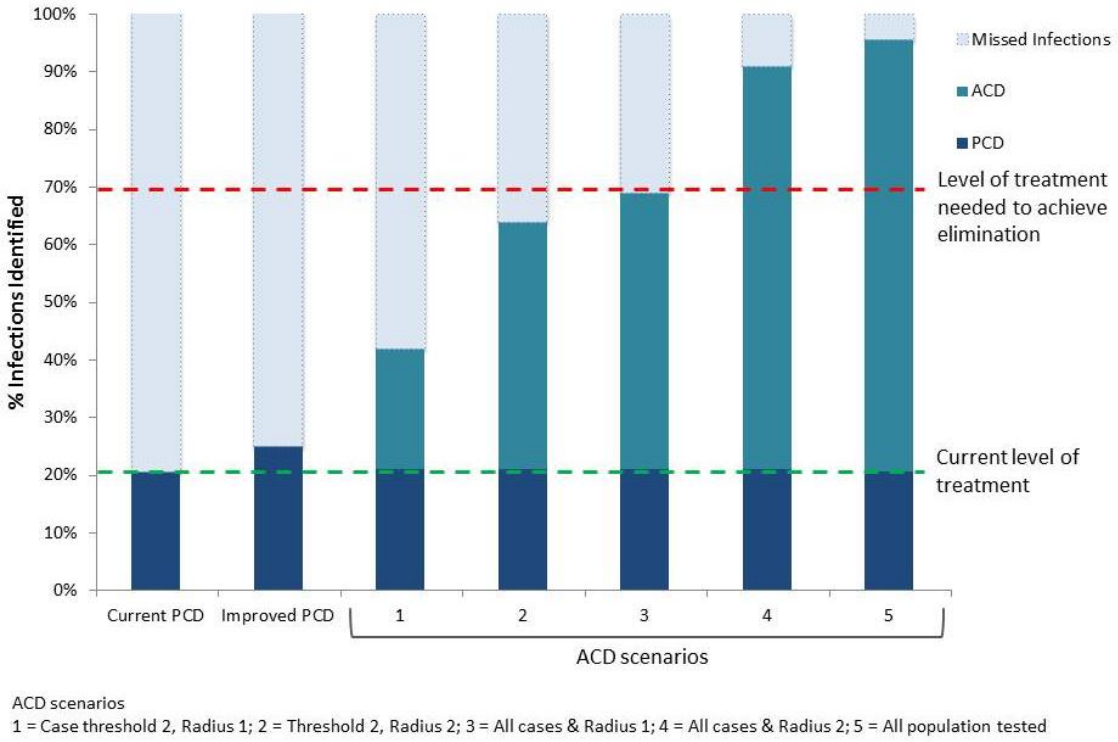


Figure 15. PR as a function of the proportion of people treated in a foci with a baseline PR of 15%, and an initial level of treatment of 20%.

At present in Haiti, malaria is diagnosed and treated through the passive surveillance system. The first line treatment of chloroquine and primaquine should be sufficient to achieve radical cure of *P.*

falciparum in this region, but detecting and treating 70% of infections as is estimated to be required for elimination is unlikely to be achieved through an enhanced passive system alone. Instead, achieving elimination will require complementing the passive detection with additional active measures to find and cure infections (Figure 16).[10]



ACD scenarios
1 = Case threshold 2, Radius 1; 2 = Threshold 2, Radius 2; 3 = All cases & Radius 1; 4 = All cases & Radius 2; 5 = All population tested

Figure 16. Proportion of infection identified according to various surveillance scenario from passive case detection to active case detection (1 to 4 corresponds to various scenarios where thresholds for investigation are decreasing, and radius of investigation increasing). The green dashed line represents the current level of infection detection in Haiti, and the red dashed line the minimum level to reach for elimination.

Active measures to attack the parasite can be broadly divided into two categories of interventions based on whether they target specific positive individuals or positive foci of transmission:

- *An individual-based parasite-focused strategy* corresponds to treating only those individuals who have received a positive malaria diagnosis by blood test. Positive individuals may be identified through the passive surveillance system when they seek care at health facilities or during active detection activities in the community. Active detection may involve testing individuals living nearby passively identified cases or proactive screens of high risk populations or locations.[68]

- *A foci-based parasite-focused strategy* corresponds to treating an entire location or community that has been determined to have a high positivity rate. All individuals within the specified location are treated regardless of infection status. Such a strategy may be implemented if it is believed that diagnostic testing is operationally impractical or tests are insufficiently sensitive to identify a high enough fraction of infections to achieve elimination.

Individual-based parasite-focused strategies

In addition to enhancing passive surveillance, active infection detection may be implemented either in the areas where cases are passively identified or in any known high risk areas (such as those suggested as high risk by the risk mapping exercise conducted here). Active infection detection involves testing individuals with a blood test and treating all of those who test positive. Blood tests may be performed on all individuals within a specified risk area, or, as was the case in many of the 1960s eradication programs, tests may only be performed on those with fever or recent history of fever.

Rapid diagnostic tests are an extremely useful tool for conducting active investigation because they are portable and provide fairly rapid results within only about 15 minutes. They have been found to be highly sensitive and specific when used to diagnose clinical malaria.[69] On the other hand, they do not appear to be very sensitive for identifying asymptomatic malaria infections, which usually manifest a much lower parasite density.[70] During community testing of asymptomatic individuals, we must therefore expect that currently available tests may identify only a small fraction of all prevalent infections. Prevalent low density infections, although likely less important for transmission on an individual basis, may still be very important drivers of transmission in very low endemic contexts like Haiti.[71]

Simulation models were used to examine the effect of testing and treating individuals (regardless of fever status) in a community of 10,000 people that may have been selected as a known high risk site. Many, if not most, infections in a community at a moment of time are likely to be asymptomatic, and thus diagnostic sensitivity may be low; we used estimates ranging between 30 and 70%. Several rounds of testing were simulated per year (between 1 and 4). Simulations showed that testing 95% of the community would achieve elimination in medium risk area as long at least two rounds of testing were conducted per year. In high risk places, this active attack resulted in substantial declines in malaria, but elimination was unlikely to be achieved (Figure 17).

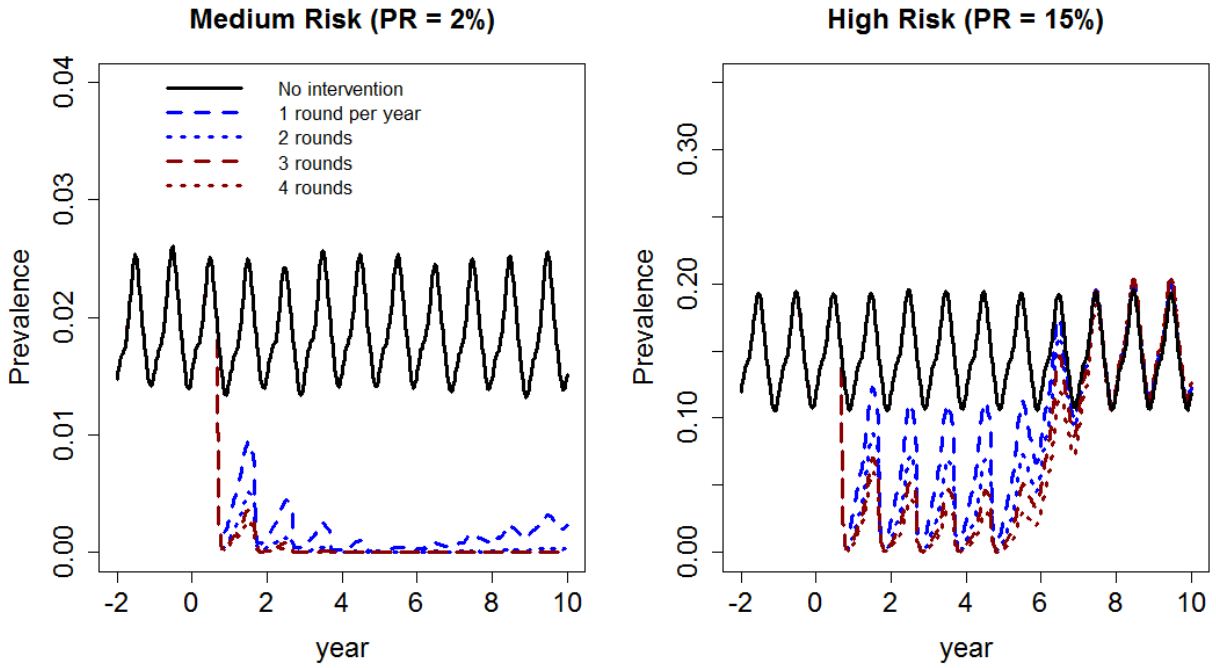


Figure 17. Testing (coverage of 95%) and treating infected individuals during low malaria season for 5 years with ACT-PQ, in foci of 10,000 people, and a level of routine treatment of 20%. Simulations are run in 2 risk areas: medium (PR of 2%), and high (PR of 15%).

Foci-based parasite-focused strategies

In local areas where positivity is very high, it may be appropriate to treat the foci in its entirety rather than treating only detected infections. This sort of approach was used to achieve short-term success in interrupting transmission in Haiti during the 1960s. Simulations of several different scenarios were undertaken. The probability of successfully eliminating malaria was dependent on the baseline malaria prevalence in the foci. Treating entire low- to medium-risk foci with initial baseline prevalence of 0.3% to 2% would achieve elimination as long as coverage of at least 90% of the foci's population was achieved at least once per year. In high risk areas, elimination would only be achieved if at least two rounds of treatment were conducted each year. In very high at-risk foci, at least four rounds of treatment at this high coverage rate would be required for success (Figure 18).

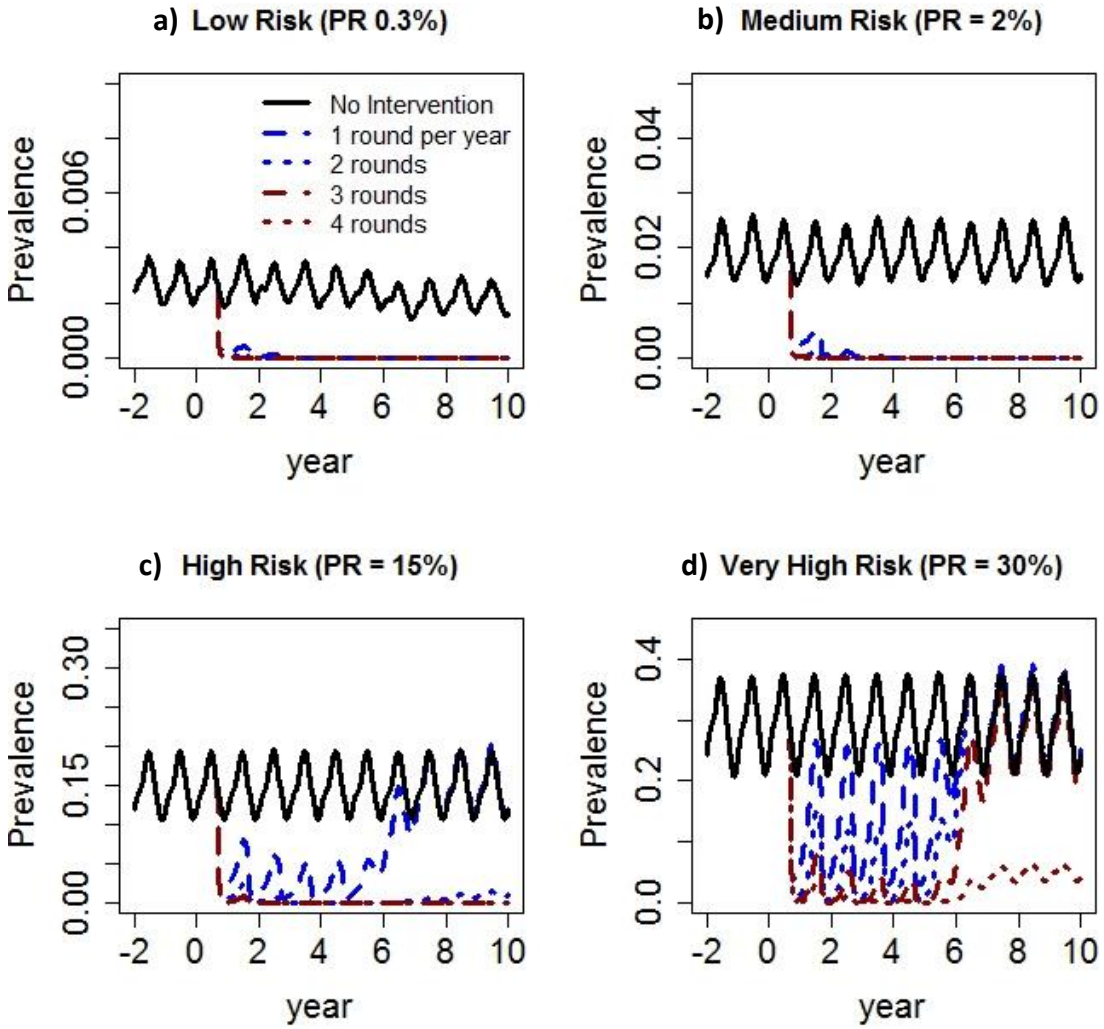


Figure 18. Strategy "Treating an entire foci" was simulated in four risk foci: a) low risk (PR of 0.3%), b) medium (PR of 2%), c) high (PR of 15%), and d) very high (PR of 30%). Drugs are distributed randomly at 90% coverage during low malaria season for 5 years with ACT-PQ, in foci of 10,000 people, and a level of routine treatment of 20%.

Besides baseline prevalence, several other factors were found to influence the success of these campaigns. These included the time frame (it is advantageous to attack during the low malaria season), whether it is combined with other interventions (ITN, IRS, or enhanced passive surveillance will all contribute to interrupting transmission), the way tests or drugs are distributed (if the same individuals are missed repeatedly in multiple rounds, a reservoir of infection will remain), the type of drug used (different drugs have different effects on gametocytes, the parasite stage that leads to transmission), coverage, number of rounds per year, and duration of interventions. Figure 19 compares the influence of four of these factors to a reference scenario that successfully leads to elimination. In the reference scenario, 95% of the people in a community of 10,000 individuals in a high risk foci (PR=15%) receive two rounds a year with an ACT combined with primaquine, and the 5% of the population missed each round is independent from round to round (in other words, the same people are unlikely to be missed every round).

- *Drug distribution mechanism*: Figure 19a depicts the successful elimination of malaria if people are missed only randomly, but Figure 19b demonstrates that if the same people are missed throughout all rounds, elimination will not occur. If a fraction of the infected population is systematically not cured, perhaps because they represent people who refuse to participate or who are inaccessible to the malaria program, those groups will be responsible for malaria persistence.

- *Coverage*: Figure 19a depicts successful elimination if 95% of the foci receives treatment, while Figure 19c demonstrates that lower coverage such as 80% would most likely not lead to elimination.

- *Type of drugs*: The impact of using an ACT in combination with primaquine in Figure 19a changes only slightly if this regimen is replaced with a combination of chloroquine and primaquine. However, Figure 19d illustrates that using chloroquine without primaquine would make elimination much more challenging, requiring four rounds of treatment a year.

- *Size of a foci*: The simulation models suggest that in smaller communities (1,000 individuals instead of the 10,000 simulated here), elimination would be achieved more easily, with fewer rounds of treatment and lower coverage requirements.

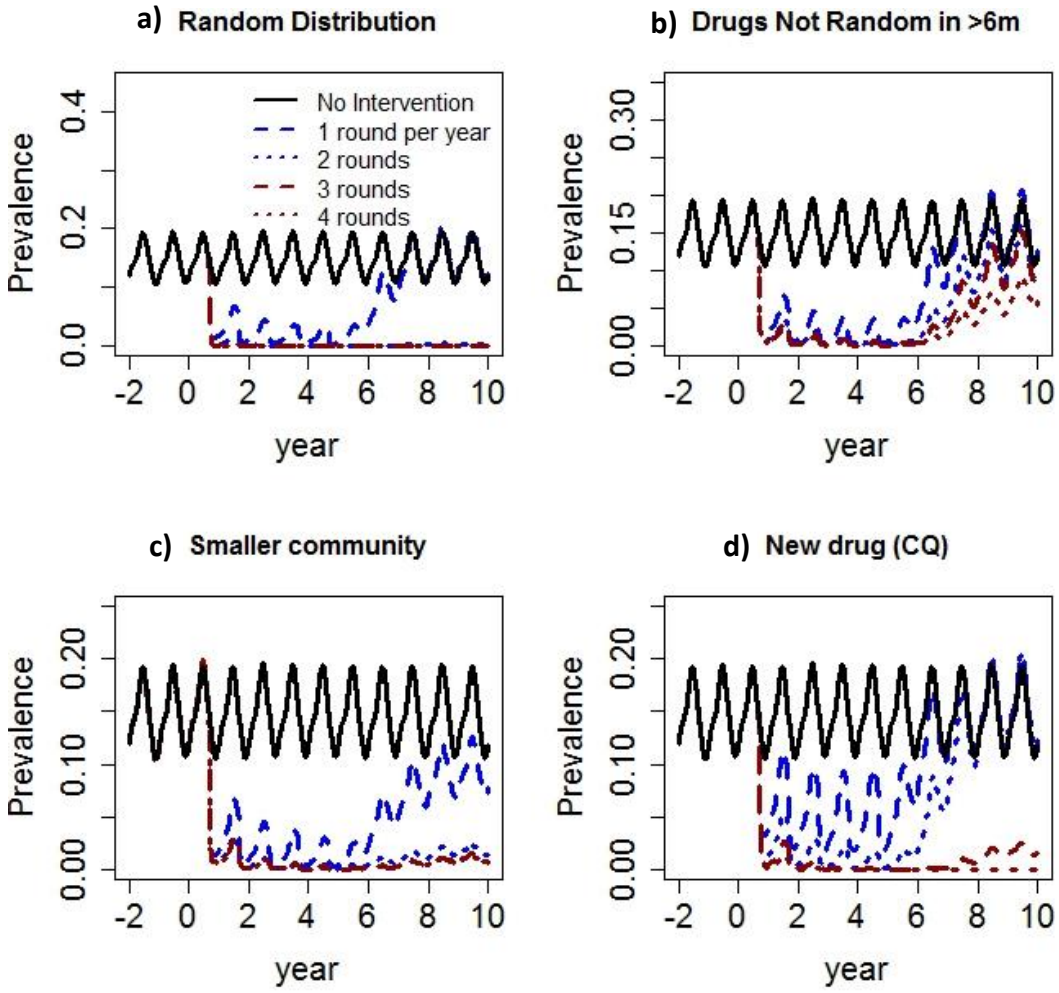


Figure 19. Strategy "Treating an entire foci" was simulated during low malaria season in a high risk foci (PR of 15%) for 5 years. Three factors were assessed: b) drug delivery mechanism (randomly or to the same people older than 6 months), size of the community 1,000 (instead of 10,000), and d) the type of drugs used (chloroquine alone instead of AL-PQ). Their impact on malaria dynamics were compared to the reference scenario - treating a community of 10,000 individuals at 95% coverage with at least two rounds a year with AL-PQ randomly distributed.

COMBINING VECTOR CONTROL AND PARASITE-FOCUSED INTERVENTIONS

These attack measures are likely to be more successful in combination rather than individually. Parasite-focused interventions may be combined with vector control intervention to attack different aspects of the malaria transmission cycle, and reactive surveillance activities focusing on individuals or foci would benefit from enhanced passive surveillance. We simulated interventions scenarios in high risk foci (PR of 15%) where treating an entire foci at 95% coverage was combined in turn with ITN, IRS, or enhanced passive surveillance. Simulations showed that both ITN campaigns and enhanced passive surveillance would reduce baseline prevalence by more than half but would not be sufficient to eliminate malaria unless 95% of the population is treated more than 4 times a year. If combined with IRS, however, treating 95% of the population more than twice a year was sufficient to eliminate malaria when combined with IRS (Figure 20).

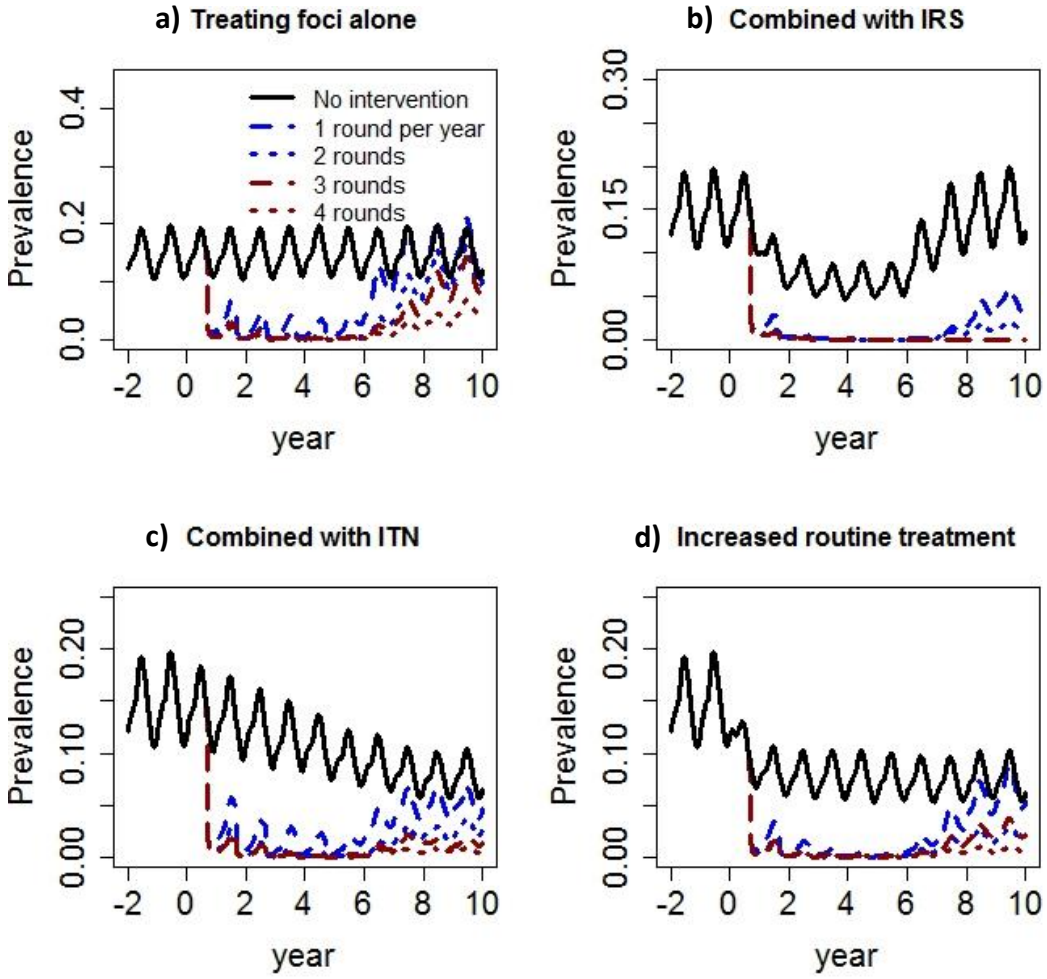


Figure 20. strategy "Treating an entire foci" was implemented in a high risk area (PR of 15%) of 10,000 people at a coverage of 95% during low malaria season for 5 years with ACT-PQ distributed to the same people older than 6 months. Campaigns were combined with b) IRS (75% coverage), c) ITN distribution (75% coverage every three years during 10 years), and d) an increased level of routine treatment from 20 to 75%.

Attacking foci strategically

The technical analysis discussed so far considers the feasibility of elimination in a closed population. As Haiti learned during the 1960s, when mass drug administration successfully achieved elimination in many communities for a short time only to see it return in future seasons, the fact that people and parasites are moving between communities will add an additional layer of complexity. Human movement must be taken into account when devising a strategic scale up elimination from individual foci to the entire country. One strategy would be to attack all at-risk foci simultaneously across the country; if the reservoir is drained everywhere all at once, there is no later risk of internal parasite movement restarting transmission. Doing so is likely to be extremely difficult operationally, however, and will require far more resources than a spatially staged approach. Understanding if such a region-by-region strategy is feasible, however, requires learning about how people and parasites are moving around the country.

One useful source of data on human movement involves records of the timing and location of mobile phone communications. Since people tend to carry their phones with them when they travel, it is

possible to assess mobility by comparing the locations at which the phones are used. Using this sort of information, it is possible to assess the connectivity between areas we have identified as being at risk of malaria transmission.[72,73] A high risk area that is only very weakly linked by movements to other high risk areas represents a place where an aggressive attack is likely to be sustainable; a high risk place that is strongly connected to other high risk places will prove a much greater challenge, however, since human movement is likely to reestablish transmission if elimination is achieved in only one of the two areas.

Human mobility was estimated using anonymous mobile phone records contributed by Digicel from 1 October to 19 December 2010. Data were provided by Linus Bengsston from Flowminder, and analyzed by Andy Tatem of the University of Southampton. The records were anonimized and aggregated at the commune level, making it impossible to identify individual users (Figure 21). These data represent only three months of communications from 2010, and may not be representative of current population movement in 2013. Further they do not take into account any potential variations in movement throughout the year. Nevertheless they provide a starting point for considering human mobility; these analyses should be repeated with more complete datasets of mobility as they become available.

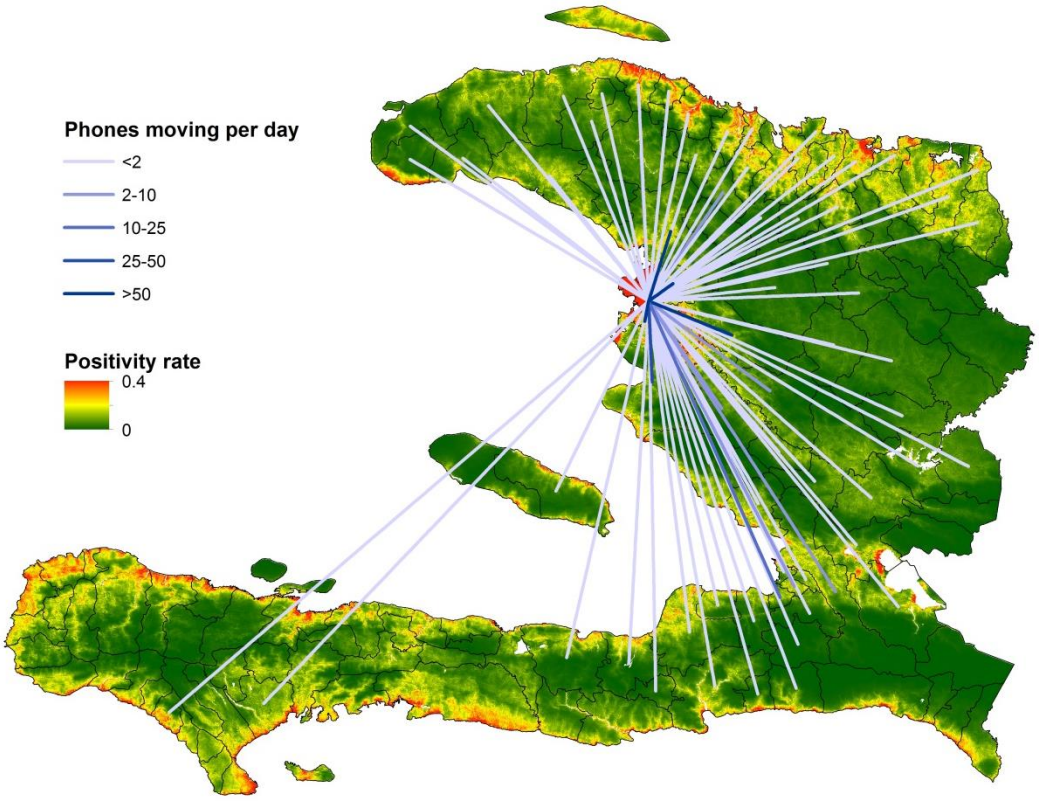


Figure 21. Example of average daily movement on the islands from one at-risk commune to all others based on the daily number of SIM-cards moving per day.

Based on this analysis, communes can be classified based on whether they tend to export malaria or import it to other regions. Knowing whether a particular commune is a net exporter (a "source") or importer (a "sink") of parasites can help design a strategic elimination campaign, since exporters are places where aggressive strategies to drain the infectious reservoir are likely to have the greatest overall effect on malaria in Haiti. The maps in Figure 22 show communes mapped by the relative rate of parasite importation (with major sinks in dark blue) at the top and importation (with major sources in dark red) at the bottom. Targeting foci located in a major source commune is likely to have an impact on malaria both at that location as well as additional foci connected to it in sink communes. Therefore, a

strategic campaign is likely to focus on implementing interventions across highly connected foci that export malaria parasites.

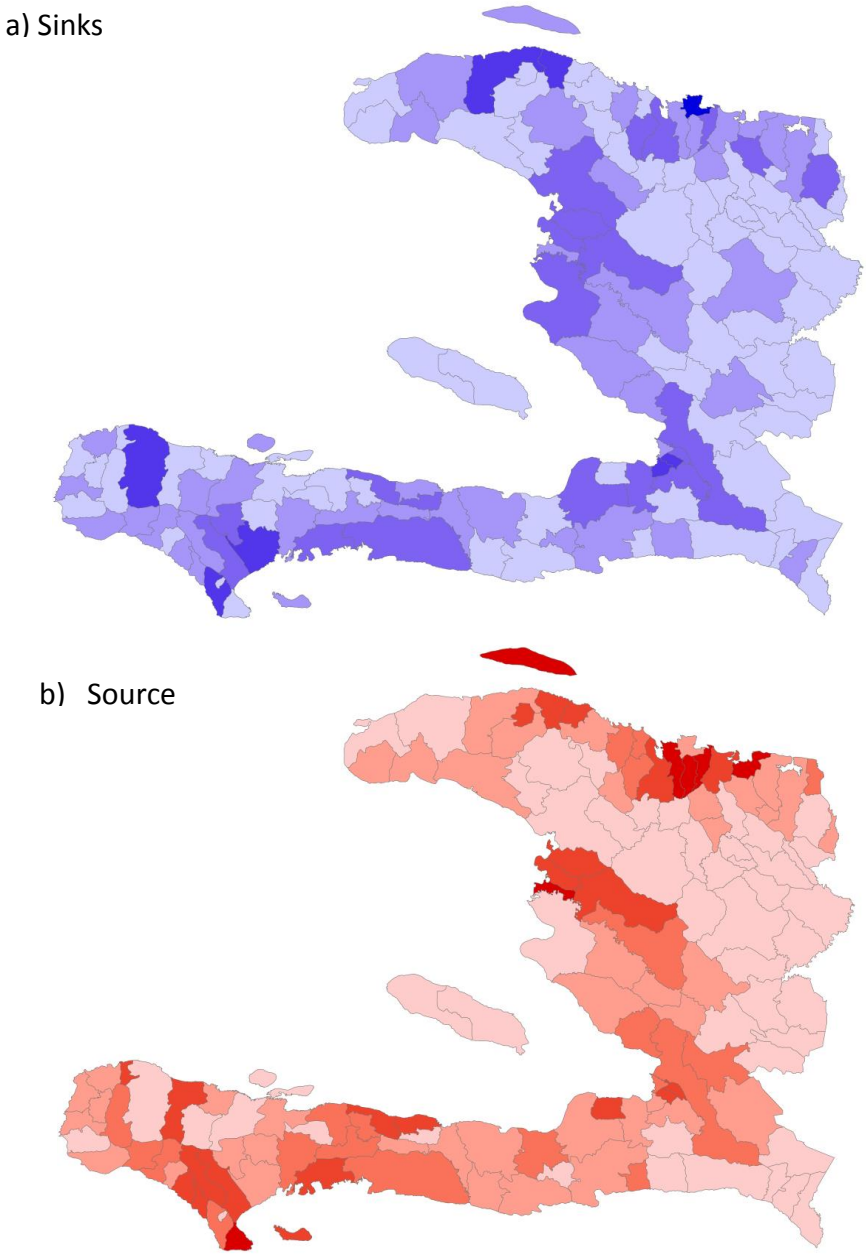


Figure 22. Communes mapped by their level of parasite importation (sinks) or exportation (sources) as estimated based on daily movement of cases weighted by the risk map (Figure 12).

Maintaining the gains

After elimination, imported malaria cases may lead to disease resurgence. [5, 74] The risk of resurgence is a function of the intensity of malaria importation, also called vulnerability. The net malaria importation rate is thought to be low in Haiti even though accurate estimates will be needed to have a more precise evaluation of risk. To mitigate the risk of resurgence, different strategies were tested using a stochastic

individual-based model developed at Johns Hopkins School of Public Health (courtesy of David L. Smith, unpublished model). Results suggest a few guidelines to ensure risk of resurgence is minimized:

- Passive surveillance should be strengthened to increase the proportion of case detected and treated. Simulations showed that more than half of new infections should be detected and cured to prevent any risk of disease resurgence (Figure 23).

- Active case detection should occur following any diagnosis of malaria in health facilities. Case investigation may include testing and treating individuals tested positive in the household, in its vicinity, or in the all community.

- An active strategy should be prepared for reacting to observed cases in foci known to be highly receptive to malaria. Such a strategy might involve rapid deployment of vector control or drugs to stem transmission and minimize risk of outbreaks.

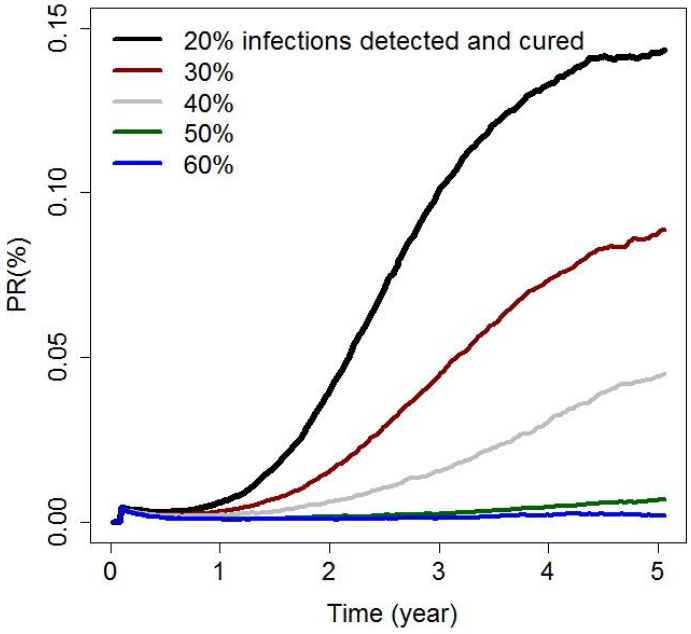


Figure 23. Risk of resurgence (PR as function of time) for various level of malaria treatment following the introduction of 50 cases in a community of 10,000 people 1 year after elimination

Technical feasibility summary

Malaria is heterogeneously distributed within the country, and, though the current risk map should be interpreted with caution in light of data limitations, it appears that high risk foci exist along the coast and the Artibonite valley. These regions will require interventions to minimize transmission and drain the infectious reservoir, with the most appropriate type or types of interventions varying according to the risk level in the foci and their degree of connectivity to other high risk foci. Simulation models were used to test a variety of potential strategies, leading to the following insights:

- Vector control alone will be unlikely to lead to elimination but will help to reduce baseline prevalence in at-risk areas;

- The passive surveillance system should be enhanced in areas of any malaria risk (approximately 6.5 million people) to increase the fraction of cases detected and treated (with a treatment that will kill gametocytes) within health facilities. At least 70% of incident infections need to be cured or prevented to reach elimination within 10 years, and 90% within 5 years. It is unlikely passive surveillance alone will reach such threshold in most places, so active strategies need to be put into place. Finally, a strong passive surveillance system would mitigate the risk of disease resurgence after elimination;

- Active surveillance should be implemented in medium and high risk places (approximately 2.2 million people), including investigation in the community after identification of a case within a health facility. Active strategies may include testing and treating individuals in the vicinity of index cases, or responding with attack measures throughout entire high-positivity locations or populations. Testing and treating individuals is unlikely to successfully eliminate malaria in higher risk places as an important fraction of infections may be missed by available diagnostics;[71]

- Treating the entire populations without prior testing of high positivity foci may be required in the highest risk places (approximately 300,000 people). Any active interventions should last a minimum of 5 years, aim for a coverage of 90% to 95%, and involve at least two to three rounds a year.

- Scaling up elimination will require implementing attack measures all at once in highly connected foci that export malaria parasites ("sources").

These results represent insights from models, but interventions based on these general guidelines should be tested out and improved through field trials in Haiti to validate them in the specific Haitian context. Models can be refined with specific parameters from Haiti as better data become available, and the risk map created here must be improved as new and more specific information becomes available; surveys of prevalence in the community in suspected risk areas, and geolocation of case households for example, would be extremely useful for improving its accuracy. Despite previously mentioned limitations, malaria elimination from Haiti appears to be at least technically feasible within five years. The sections that follow will explore the operational and financial challenges to implementing the technical recommendations described here.

OPERATIONAL FEASIBILITY

Elimination appears technically feasible within only about five years, but its success will also depend upon operational feasibility, or whether achieving technical requirements is truly possible given the realities of infrastructure and the geographic, social, political, and economic conditions.[76] Weaknesses and constraints in the health system and current response can slow down progress or even negate altogether the possibility of achieving elimination, unless they can be adequately addressed and reinforced.

Operational feasibility was assessed through semi-structured interviews with MSPP personnel in different directorates, personnel from other Ministries, former members of the SNEM and the malaria program managers and leaders of organizations working in malaria. Group discussions were also facilitated at the Salle de Situation and at the quarterly Sub-Recipient meeting for the GFATM grant. Reports on the malaria programs were reviewed. Tools and systems shared by the program and partners were also analyzed to understand their adequacy for use in an elimination campaign. One trip to the Dominican Republic allowed for similar, although more limited exchanges, on the readiness of the program in the DR to undertake an elimination campaign.

In the case of Haiti, the discussions concluded that there are important operational constraints and if no system strengthening is provided, active case detection efforts would be difficult to successfully implement and achievement of elimination would be unlikely.

To achieve the requirements set forth by the technical assessment and achieve elimination, the program will need to strengthen its current efforts by focusing on three broad areas:

1. Improve systems for the identification and treatment of malaria infections, including both passive and active measures;
2. Target attack measures, including both vector control and parasite-focused methods as appropriate, to transmission foci with sufficient coverage to eliminate transmission in a strategic way that accounts for population movement;
3. Strengthen the government's ability to lead, coordinate, and learn from the implementation of the elimination campaign;

In addition, the program will need to plan proactively for a post-elimination program that will be sufficient to manage ongoing risk and prevent reestablishment of malaria transmission.

Improving systems for identification and treatment of infections

A vital component of an elimination strategy is timely and accurate knowledge of where malaria transmission is occurring. The more infections that the health system can identify, the more efficiently interventions can be targeted to true risk areas. Additionally, identifying and curing clinical cases as they occur will halt new contributions to the infectious reservoir and increase the program's ability to achieve elimination. Although several different strategies may be employed to reach these goals, there are several fundamental conditions that must be in place.

PASSIVE SURVEILLANCE STRENGTHENING

Passive case detection, or the diagnosis and treatment at health facilities or health posts and their timely reporting to a centralized system, is the backbone of a case identification system. In Haiti, passive

case reporting is currently done through two health-system wide efforts, the health information system (HSIS) and the national sentinel site surveillance system (NSSS), as described earlier in this report. The utility of the health system for informing where malaria is occurring and rapidly treating incident cases depends on a cascade of factors including:

1. The fraction of infections that are symptomatic;
2. The fraction of clinical illnesses which seek treatment;
3. The fraction of suspected malaria cases that are laboratory confirmed;
4. The fraction of confirmed cases that receive and adhere to appropriate treatment;
5. Timely and complete reporting of all malaria cases to the regional or national systems.

Neither system currently in use will be sufficient for elimination purposes. HSIS data collection is incomplete, inaccurate, and not timely, and while the NSSS was created to fill these gaps for the most essential indicators, it only covers one eighth of institutions in the country. The HSIS includes all private, public, and mixed sites and would thus be the ideal information system to serve as the basis for identifying malaria cases. However, there are important challenges of data accuracy, data completeness and data timeliness. For example, indicators are interpreted differently across sites, due to minimal training and supervision of site personnel and managers. In addition, with the roll-out of RDTs and an increased confirmation rate, it will be critical to ensure that not only suspected cases, but also the number of tests completed and the number of laboratory confirmed cases of malaria are reported.[c]

Treatment seeking

The effectiveness of passive case detection depends on people contacting health services. According to data collected during the 2011 PSI survey, 46% of the population report accessing treatment when they have a fever. Of these people, 75% consult a doctor or community health worker. Common barriers to treatment-seeking reported by the Haitian population are described in Figure 24. People may also not seek care due a perception that febrile disease is not generally severe. Respondents in the 2011 PSI survey had an overall perception of severity of 2.83 out of 5, based on questions about mortality, financial impact on their household and effect on child development.[61] From 2009 to 2011, the percentage of people that believed malaria was dangerous for children decreased from 44% to 33.5% of the population. Intensified communication activities about the importance of seeking treatment can help drive fever cases towards health facilities (and will also be essential for ensuring the acceptability of active surveillance efforts once they begin).

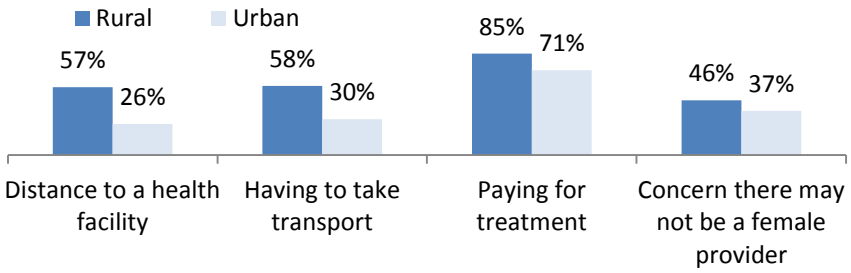


Figure 24. Common reasons for not seeking treatment for febrile illness.

[c] The MSPP is in the process of adding RDTs to lab registers.

The ready availability of chloroquine in private pharmacies and the informal sector combined with widespread awareness that it is the appropriate treatment for malaria also leads some individuals to self-treat their illness. Adapting communication messages to address this challenge will be important if the program is to know where infections are occurring and ensure that appropriate treatment is given. Structural barriers, including cost and distance to facilities, also affect whether a patient will seek treatment. As illustrated in Figure 254, people living in rural areas are disproportionately affected by such barriers. Major hospitals are concentrated near the capital, and 65% of the population is served by only 33% of the doctors; rural sites also close earlier, forcing people to come farther earlier in the day.[d] Financial barriers are also high. According to the National Health Accounts for 2005-2006, about 54% of malaria expenses are paid by Haitian households, compared to 52% for all health expenses and 2% for HIV/AIDS.[77] The cost of tests and treatment should be free for the patient; however, patients often pay consultation fees in public health facilities and even higher prices for services at the 45% of sites that are private.[78] The highest levels of the MOH should communicate to public institutions that they are now required to provide free services and undertake an awareness campaign on the right to free testing and treatment for malaria. Training community health workers to seek out, test, and treat fevers in the community, as done successfully in the cross-border Carter Center/CDC project in the North-East region, would allow the program to reach those affected by structural barriers.

Case management

To achieve elimination, every health facility in the country must be adequately equipped to diagnose, treat, and report cases of malaria. All patients arriving at a clinic in known risk areas should be asked about their fever history, and all fever cases should receive a malaria test. All patients with positive malaria tests should receive both chloroquine and primaquine per treatment guidelines, and patients should receive counseling on the importance of completing the treatment course. All medical personnel at health facilities would benefit from reinforced training on these guidelines.

Until very recently, all malaria diagnosis was done in Haiti with microscopy, a service that is currently available at approximately 400 health facilities. There are insufficient human resources to conduct post-training supervision or certification in these techniques and informal studies have shown low accuracy of tests run by lab technicians in the country.[e] Additionally, recent research has demonstrated that microscopy will not identify low density (usually asymptomatic) infections that may still be contributing to transmission.[62,70] Although RDTs suffer from the same problems as microscopy with regard to identifying low density infections, they require less supervision and training than microscopy. In 2012, CDC scaled up RDTs to 40 health facilities/dispensaries without labs, with the goal to reach 90 by the end of the pilot in 2013. The GFATM Phase II proposal includes the continued provision of RDTs to CDC pilot sites and scale-up to 100% of the facilities in the country by 2015. This scale-up will require coordination of the supply chain, training of health workers, and intensified supervision at health facilities to ensure proper use and uptake. Distribution of commodities to public facilities relies on health personnel from the sites proactively picking up commodities from a departmental warehouse.[f] In addition to improving the ability of sites to monitor stock, an active form of regular distribution to the

[d] There are only 2.3 personnel per 10,000 inhabitants in Haiti. This is markedly far from the WHO standard of 22.8 per 10,000 inhabitants. Moreover, while there are 7 personnel per 10,000 inhabitants in Port-au-Prince, there are 0.2 in cities in other departments MSPP Haiti. "Audit Organisationnel MSPP : Rapport." November 2010. PARC. "Analyses et Projection: Recensement des Ressources Humaines en Santé en Haiti 2006-2012." Ctd. in Dalberg. "MSPP Organizational Audit : Presentation of Preliminary Findings." September 2010.

[e] Interview with the National Lab (LNSP).

[f] National Strategic Plan Workshop Notes, 2012.

sites should be investigated. This could include integrating products into existing supply chains for HIV for example.

At Haiti's low level of prevalence, some infections will not be detectable by RDTs or microscopy. It is therefore critical that the LNSP's policy of conducting quality assurance by PCR of 10% of negative tests and all positive tests using PCR is consistently implemented, which is not the case right now due to lack of resources and logistical constraints. The LNSP policy should be clearly documented and the importance reinforced to departmental technicians and health facilities across the country. The processes of moving samples from the facilities to the LNSP could be reviewed and additional funds allocated for ensuring this occurs. The LNSP will need additional trained personnel to analyze the increased number of samples, and potentially an additional machine.[g] The LNSP must also be pro-active and systematic about providing feedback on the results and ensuring that departmental lab technicians work with health facilities to improve performance where needed.

The recent modification of the treatment norms to add single dose primaquine to the first line treatment regimen may help clear gametocytes and reduce transmission. The uptake of primaquine has been slow, however, and the CPNMFL must disseminate the new norms as widely and quickly as possible and ensure that sites have a continuous supply of drugs. At each visit, the departmental teams responsible for supervision should verify that the stock is available and being prescribed. Whether or not an infection is cured may also be affected by patient adherence to treatment. CHWs in the MSPP/CDC border commune project and in the Dominican Republic check-in on patients in day two and three of treatment, but this is not a part of the national protocol in Haiti. The expansion of the role of CHWs at health facilities to follow up with patients with malaria could prove beneficial, although it would require hiring more CHWs and modifying training.

Case reporting

Many sites never report, report inconsistently, or submit incomplete reports. Reasons include a lack of understanding of the indicators and the importance of reporting, as well as personnel feeling overburdened and overworked. Even when reporting occurs, there is a significant time lag between case identification and case reporting. Given the many varying reasons behind this, a multi-pronged improvement strategy will likely prove necessary. Additional training or communications from the highest levels of the MSPP on the importance of submitting this data could also help to speed up reporting and increase the number of sites reporting. Updating the definitions of the HSIS indicators to reflect the new emphasis on case confirmation will increase the quality of the data reported. Ensuring accurate, timely reporting will require refresher training for all personnel involved in reporting at each health facility in the country, which could be integrated into training on treatment norms or the roll-out of the M&E plan. Each site should have copies of the indicator definitions available to consult. Additional resources will be required for the departments to ramp up supervision, at minimum during the first few months following the refresher training. Specific efforts targeted to the private sector that have very low levels of reporting may be necessary to increase their coverage. Providing the departments with additional resources for follow up with the health facilities in their regions could also be beneficial. Implementing an incentive system, not necessarily financial in nature, may help increase staff motivation.

The NSSS has much higher levels of data completeness, accuracy and timeliness than the HSIS. However, the NSSS only includes 107 sites, and though the government aims to scale this network up to all sites,

[g] Interviews with sub-recipients.

progress towards this target has been slow. As a potential next step, the government could consider scaling-up the NSSS system by including new health facilities that are located in the areas of greatest risk of malaria transmission. Reporting at current NSSS sites requires strengthening as well. Currently, case-level information must be retrieved on-site from institutional registers and even there, the registers are often missing patient domicile information. The CPNMFL does receive some NSSS results weekly and the government is currently making these results available on a public website.[h] An add-on case-specific system that allows confirmed cases with patient geographic information to be reported immediately to the CPNMFL would be ideal to support the program to mark cases on the risk map and conduct reactive case detection using a spatial decision support system. Such reporting could be implemented through text messaging, drawing on the system used for cholera surveillance in the country. Few areas in rural Haiti have official addresses, so where an address is not available, the program should identify techniques for geo-locating patients that are appropriate to Haiti, such as using landmarks to locate the patients' addresses, until GPS-equipped field teams can be deployed to investigate cases. The Dominican Republic's CENCET is currently automating their case reporting, so there is an opportunity for coordination of an island-wide surveillance system to support elimination operations.

Strengthened supervision and verification at all levels of the health system from site managers to departmental and central level personnel at the CPNMFL, UPE, and DELR could help address many of the weaknesses in the reporting system. Building such a supervision system will require the mobilization of additional funding for data validation visits, as well as training of the epidemiology and M&E units in better supervision techniques. With more immediate access to data, the CPNMFL could conduct additional remote validation and focus these intensified data validation efforts on health facilities that would require the most capacity building.

Analysis and utilization

Identification and reporting of cases are vital, but this information must be analyzed on an ongoing basis to ensure interventions can be adjusted as needed in response to changing epidemiology. A GIS system for mapping cases and revising risk maps on an ongoing basis should be set up, using a common framework that allows easy overlay of coverage maps to understand weaknesses and adjust attack measures on a daily basis. Such systems have been implemented elsewhere.[79] The malaria teams at both departmental and central levels involved in epidemiology, M&E and planning should meet to review the data and decide on courses of action (see Figure 25 for an example of a useful map with commune-level aggregation for planning activities).

[h] www.mesi.ht is a publicly available website where the MSPP posts M&E data, historically for HIV.

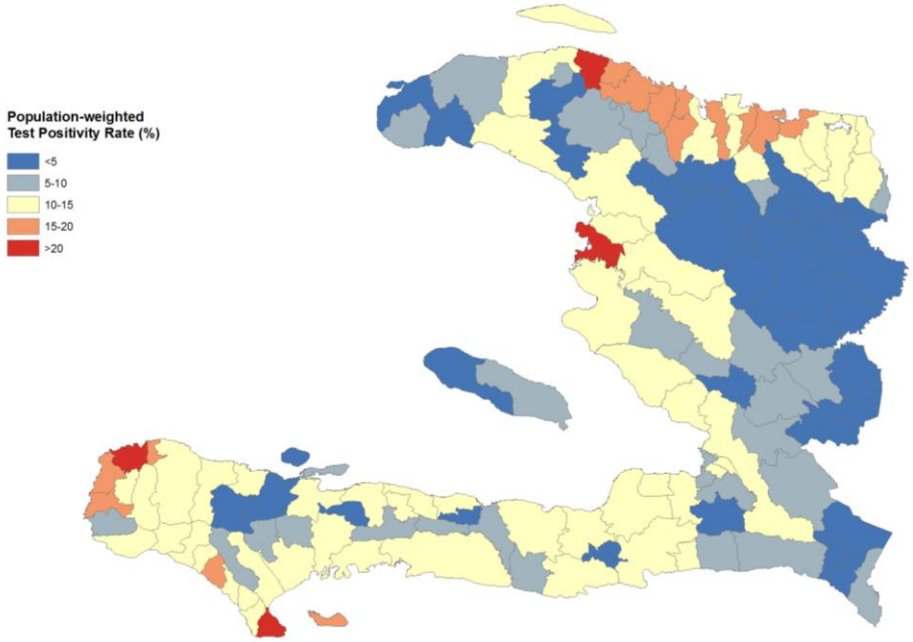


Figure 25. Regional test positivity rate estimates extrapolated from risk mapping

To ensure available case data is being analyzed and applied for decision support on an ongoing basis, it will be essential that epidemiologists and GIS analysts at the national and departmental-level are hired and well-trained in risk mapping, and data analysis to help decision makers interpret the results appropriately. All central and departmental staff that plan or supervise activities will also require basic training in interpretation of the data and also in the importance of using this data to inform their work.

Implementing clear mechanisms that define how the central level and departmental level work together to address detected cases will help the program ensure that all cases are followed up with appropriate strategies. In addition, regular departmental-level meetings to review trends and establish action plans can also help ensure that the data is being translated into action**.**

COMMUNITY SURVEYS

Historically in Haiti, health facility surveys have been relied on to estimate slide positivity rates. More recently, population-based surveys have been conducted through the GFATM grant to measure parasite prevalence at a population level along with insecticide-treated bed net ownership and usage. The 2011 PSI survey, conducted using microscopy, RDTs, and confirmation by PCR during one of the peak transmission seasons, found a parasite prevalence of 0.9%.[61] Results of the 2012 survey are not yet available.

Given the apparent heterogeneity in transmission described previously, future surveys should be designed to inform risk mapping and not only to derive a single national estimate of malaria prevalence. Next year's population survey could be expanded for this purpose to include more sampling in the rural regions believed to be at higher risk of malaria transmission. Additionally, rapid transmission assessment surveys could be completed, using small samples in many locations and oversampling in suspected risk

areas. Such surveys would inform the program on the variation in prevalence across the country, and provide increasingly accurate data for targeting interventions. Each case should be geo-referenced to enable mapping.

Table 7. Summary of Surveillance Recommendations	
Treatment-Seeking Behavior	• Communicate to all public and mixed health facilities that they are required to provide free malaria services. • Run awareness campaigns on the risks of malaria transmission.
Diagnosis & Treatment	• Distribute RDTs to all departments and institute a method to regularly, actively distribute these tests to dispensaries. • Validate and disseminate the care and treatment norms, providing training to site personnel. • Allocate additional resources towards the supervision of institutions, ensuring the new norms are addressed. • Conduct additional quality assurance on rapid tests using PCR.
Reporting	• Motivate health institutions and the departments to report on time. • Train health workers to test all suspected cases, treat confirmed cases appropriately, and report all required information including geographic location of the patient. • Create an add-on system for timely reporting of case-level information to the CPNMFL.
Data Utilization	• Train personnel including epidemiologists and GIS specialists to update risk maps and analyze case data to target the response. • Review case-level data systematically to identify hotspots and inform the selection of attack measures.
Surveys	• Conduct rapid transmission assessments using small samples in many locations and oversampling in suspected risk areas. • Modify the population-based survey so it can serve the dual function of showing country-wide prevalence and reinforcing the transmission risk map.

Targeting attack measures

ATTACKING THE VECTOR

The technical feasibility assessment determined that though vector control efforts are not likely to eliminate malaria on their own, they can play an important role in the drive towards elimination in combination with other strategies. Vector control played a key role during the SNEM's elimination efforts in the 1960s. Since the end of the SNEM, with the exception of the 2012 LLIN distribution campaign, vector control efforts have been less comprehensive, limited by logistical and funding constraints.

In order to maximize their contribution, vector control activities must be well-coordinated and targeted towards risk areas. Vector control may play a particularly important role in "sink" areas that import malaria parasites from elsewhere, as it can reduce the probability of transmission from these imported cases over time while the parasite reservoir is being drained in the "source" areas that export infections. Vector control is resource intensive both in terms of human and financial resources, so the choice of vector control techniques should be informed by careful evaluation of their effectiveness and their cost.

All vector control activities should be geo-located for inclusion in decision-support databases and risk mapping.

Insecticide-treated nets

Nets were distributed following the 2005 outbreak in the Artibonite and in a mass campaign in 2012. In addition, there have been some ad hoc distributions by partners, with a particular focus on internally displaced persons (IDP) camps post-earthquake.i These distributions occurred despite concerns regarding their effectiveness given the vector's outdoor-biting and outdoor-resting behavior. As a result, CDC and MSPP/PSI are conducting an LLIN case-control study that will help clarify the protective effect of LLINs in Hispaniola. If study results prove positive, targeted distribution in medium or high transmission risk areas could continue to suppress transmission. Based on the recent experience in mass distribution, distribution via existing channels such as health centers, vaccination campaigns and community organizations may help the program avoid the challenges faced in the previous mass campaign, such as theft.[j]

While waiting for the study results, net utilization should be strongly encouraged to maximize the gains that can be achieved from the 2012 distribution. The EMMUS V study in 2012 showed that of the children under 5 living in households with a mosquito net, 51.6% had slept under the net the night before. In the interviews conducted for this evaluation, anecdotal reports suggest that net usage is limited because people felt too hot or did not know how to install the net. In a household survey conducted by PSI in 2011, 27.6% of respondents had been exposed to messages on malaria prevention, such as net utilization. Those that owned a mosquito net were found to be three times more likely to use it if they had received such messages.[61] One way to build on these education efforts could be to leverage existing NGO teams of community health workers to follow-up with net recipients to encourage proper use.

Other vector control strategies

Besides net distribution, vector control measures currently practiced in Haiti include larviciding and destroying larval habitat, as well as adult vector measures such as fogging. Larviciding has proven successful in certain settings, but it requires specific knowledge of the locations of breeding sites.[80] Source reduction is conducted *ad hoc* in collaboration with the Ministry of Environment. These efforts include draining stagnant water in populated areas and installing irrigation systems. Adult measures such as fogging are not conducted systematically; pumps are available at the MSPP in the case of an epidemic. Rigorous evaluations of the effectiveness of the different techniques used at interrupting transmission have not yet been completed, and are recommended to ensure that resources are spent on the most effective techniques for the specific contexts in which they are being implemented.

The large majority of vector control activities being conducted in Haiti are done through the CPNMFL and the health departments. One other sub-recipient of the GFATM grant conducts vector control activities in the Côte des Arcadins region and the Cuban Medical Brigade investigates and treats larval habitats that are within 100 meters of their clinics and the homes of their health workers. The national strategy calls for 5-person brigades in each department to undertake vector control activities, only some of which are currently operational. Although dependent on the type and size of the habitat and the distance between habitats, a 5-person brigade can generally cover between 200 and 400 larval habitats

[i] For example, in 2010 UNICEF distributed mosquito nets to families living in camps. http://www.unicef.org/lac/media_18886.htm

[j] The National Strategic Plan specifically states that distribution of free mosquito nets is essential to achieve the goal of elimination, which has perhaps prevented actors from exploring other mechanisms such as social marketing. CPNMFL. "Plan Stratégique National." 2013.

a month. While inventory of habitats is not yet complete, a department such as the North has approximately 1,000 larval habitats, whereas other (typically lower endemic) departments such as the Center may have fewer than 100.[k]

Decisions taken on how or if to treat a larval habitat or conduct other vector control activities are currently not being informed systematically by data on confirmed cases near the habitat. The effectiveness of the brigades could be increased by ensuring team operations inform and are directed by the departmental epidemiologists and M&E officers to focus the types and locations of the attacks. Linking the information in the larval habitat database to the database of confirmed cases would create a useful decision tool to inform which larval habitats are to be prioritized for treatment. Additionally, not all vector control activities are accepted by the communities due to factors including environmental concerns. Where vector control is appropriate, coverage can be reinforced by educating and involving community health workers to identify habitats and raise awareness in their communities. CHWs can ensure that the population is receptive to vector control activities, and provide additional manpower for managing habitats in high transmission foci.

Entomological surveillance and research

Entomological surveillance includes the monitoring of factors including vector behavior, density, infection rates, and susceptibility to intervention measures. Such measure can be important tools for an elimination program to identify and monitor transmission foci, receptivity to transmission or re-infection, and the effectiveness of interventions. To date, entomological surveillance has been somewhat *ad hoc*. The MSPP is conducting a national mapping of larval breeding sites with the support of the IVM brigades and volunteers, though data is still being entered and does not include GIS coordinates. The GFATM phase II proposal includes provisions for vector samples collected by the brigades to be analyzed at sentinel sites for species identification as well as insecticide resistance. CHWs involved in the Centre d' Appui aux Politiques de Santé (CAPS) project measure larval density in one region of the country where there was an epidemic in 2005. The Cuban Medical Brigade also performs regular larval density measuring and additional entomological research projects are conducted with universities and consultants linked to the LNSP.

To coordinate and strengthen these activities, the MSPP, via the CPNMFL and the LNSP, will need to create a regular research forum with partners where the country's research priorities are shared and coordinated, study results are disseminated and analyzed and recommendations can be made on program improvements in light of findings. As a first step, the entomological information that has been gathered through this elimination feasibility assessment is available in a searchable Excel database. This database should be updated by the CPNMFL with results of studies currently underway. Expansion of entomological surveillance and research will require additional field collection and lab capacity at the MSPP. This includes adding field and management personnel at the central level, procuring GIS equipment, and providing necessary training.

[k] Interview with the CPNMFL. March 2013.

Table 8. Summary of vector control recommendations	
General	• Target vector control approaches to high transmission areas and ensure measures are coordinated and implemented strategically. • Involve community organizations and CHWs, formalizing their role in the response.
Nets	• Implement community mobilization strategies to increase net utilization while waiting for the results of the net effectiveness study.
Other Vector Control Measures	• Ensure the work of brigades is targeted according to surveillance data, and potentially train them to assist in other aspects of the elimination program, including case detection. • Conduct evaluations of vector control techniques to determine what vector control measures are most effective in the Haitian context. • Ensure larval habitat data is geo-located and linked to the epidemiological data.
Entomological Surveillance	• Encourage researchers to pool entomological research results to better target future studies.

ATTACKING THE PARASITE

As discussed in the technical assessment, increasing the fraction of infections being cured will be essential for achieving elimination. Doing so will require complementing passive surveillance strengthening with active measures to seek out and cure infections in the community regardless of disease status. Two categories of active parasite-based approaches were discussed in the technical assessment: "individual-based" attack involves testing individuals and treating all who test positive, while "foci-based" measures involve identifying focal regions with high positivity rates and treating everyone within them. Either approach can be performed reactively, in which case intervention occurs in response to a particular trigger, such as a passively identified case; or proactively, in which intervention occurs in certain locations or populations that have been classified as high risk (such as those areas classified as potential high transmission sites on the risk map) without a specific trigger event.

The specific protocol for when and how reactive or proactive measures should be employed should be devised strategically, but approximate guidelines for the number of rounds and coverage required by these sorts of measures are provided in the technical assessment. The government will need to develop guidelines and standard operating procedures for how these interventions are to be conducted. Health facilities will need to hire additional CHWs or re-organize the work of current CHWs to support the additional workload that following cases into the community would require. Some CHWs in the Artibonite, Ouest and Nord-Est departments have already begun implementing reactive case detection strategies. However, currently only those in Ouanaminthe are trained to conduct testing with RDTs.[I] Vector control brigades could also be trained to conduct these investigations in coordination with their other activities.

Modeling suggests that individual-based parasite-focused attack measures may serve an important role in interrupting transmission in lower risk regions. Field trials will be needed to corroborate these results and identify the most effective techniques from cost, logistic, coverage and acceptability standpoints.

[I] This project is funded by CDC, and is based on the principles of an earlier project by the Carter Center.

These sorts of approaches involve testing all individuals in a known risk area (determined either in reaction to observed cases or proactively in predicted risk areas or populations) and treating all who test positive with a drug regimen sufficient to achieve radical cure. Doing so will require large investments in human resources, including community health workers and nurse supervisors who will be responsible for testing, treating and reporting on cases. These workers will require training in using rapid tests, in dispensing medication, and in communication and in case reporting. Directives from the MSPP will be required stating that community health workers are allowed to perform such tasks. Both CHWs and nurse supervisors will need training in how to track for adverse events caused by primaquine and ensure linkage to the nearest qualified health facility that can handle such cases.

Current reporting tools and systems are not currently adapted for such active measures, and the program will need to design a new system that will be adapted for field activities, while still be consolidated with the current HSIS and NSSS systems. An effective system might involve mobile reporting of the locations at which individuals were tested, the results of those tests, and whether treatment was administered. CHWs will need to be equipped with GPS units and mobile devices in addition to the necessary lab supplies and pharmaceuticals. A useful first step conducted in most eradication programs during the 1960s involved an initial census of the population, including mapping of all houses in risk areas. Assigning all houses and inhabitants a malaria elimination number will facilitate reporting to the centralized database and ensure an accurate accounting of who has been tested and treated and where infections are being identified. Modern technology like remote sensing can facilitate such map creation by identifying households based on classification of satellite imagery.

At higher transmission intensities, models suggest that entire populations of high-risk foci may need to be treated to achieve complete interruption of transmission. Treating positive foci without testing raises additional questions and challenges. When considering the option of treatment without a blood test, the program must take into account the ethical consideration of whether it is appropriate to give medication to people who are not sick, given that there is some risk of adverse events, particularly with primaquine. There is a history of mass treatment in Haiti, both for malaria in the 1960s, and very recently for lymphatic filariasis. Additionally, recent experience in distributing nets across nearly all of Haiti suggests that achieving national coverage with interventions is possible, if operationally challenging. Learning the lessons of these prior campaigns will be critical for ensuring that treatment of malaria foci is conducted at sufficiently high coverage and with sufficient safeguards to ensure success.

One of those lessons is the importance of clearly communicating with the communities in which the program is to be conducted to ensure its acceptability. The acceptability of the active detection measures selected will be a defining criterion for the success of malaria elimination and will require community mobilization efforts. CHWs are likely to be the cornerstone of these efforts, reaching out to the target populations in their homes, at clinics, at community meetings, and at mass events. The program can also leverage current community mobilization strategies such as training of community leaders (pastors, mayors and members of community-based organizations) and hosting of peer education activities and community meetings. Actors involved in information, education communication (IEC) for case detection will need to be flexible, and able to move from community to community as malaria epidemiology needs change or as different communities exhibit different levels of acceptance of strategies deployed.

When treating communities at large scale, there is an argument for using a different medication than the usual first line treatment to protect against chloroquine resistance. ACTs have proven to have substantial activity against gametocytes and will thus help reduce transmission; additionally, long-acting drugs like DHA-piperaquine can have prophylactic effects that may catalyze even greater declines. On

the other hand, ACTs tend to be substantially more expensive than chloroquine. The program will need to weigh the advantages and disadvantages carefully in making this decision. If an option other than chloroquine is selected, treatment norms will need to be adapted, trainings with healthcare workers conducted, and the program will need to collaborate with the pharmaceuticals and traditional medicine (DPM/MT) to ensure rapid approval of the new drug for importation and use.

Regardless of drug choice, continued monitoring for drug resistance will be important to ensure that the parasite remains sensitive. In the past, chloroquine resistance surveillance has included periodic and geographically specific surveys as well as regular sentinel surveillance.[m] PSI and CDC are currently setting up a network of four sites that will send 100 samples during each transmission period to the LNSP. The LNSP will also be the only referral lab for PCR testing and quality assurance.[n] Drawing on lessons from GHESKIO's previous experience with PCR, existing mechanisms should be leveraged to decrease the cost of transporting samples. This includes, for example, using supervision visits for sample transport.[o] Lab technicians should be sending samples with suspected resistance to the LNSP, though this rarely occurs in practice.[p] The number of resistant cases is currently an indicator in the HSIS monthly report. However, site personnel often mark this indicator at the first sign of treatment failure, rather than investigating patient adherence or researching whether the patient did not actually have malaria. When disseminating the new norms, the program should conduct refresher training for personnel on treatment failure and for lab technicians on the procedure for sending a sample for suspected resistance.

Managing mobility

Understanding population movements both within and between countries will be critical for designing an attack strategy that is targeted, effective, and able to achieve sustainable gains. A first priority is thus to ensure that the program understands where cases are originating. All case reporting should include information on the travel history of the patient during the prior month, including where they live. This information must be fed into the centralized database to enable detailed analysis of where infections are originating over time.

The program should work with partners to understand the major movements of migrant populations, such as agricultural or construction workers. The movement of these workers tends to follow defined patterns, and by working with other ministries, such as Agriculture or Public Works, the program can proactively identify where communication and testing will need to occur. Identifying organizations that provide other services to these populations will provide a good entry point to scaling up activities amongst these groups, as is done currently in the DR with associations of Haitian and Dominican workers that are sub-recipients of the GFATM grant. Currently, there are border personnel asking people at Haiti-DR crossings if they currently have a fever; such border screening can be challenging depending on the volume of crossings and may slow necessary traffic, but consideration of the potential costs and benefits of such an approach should be undertaken.

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[m] This plan says it is necessary to conduct surveillance twice a year during peak transmission.
CPNMFL. "Plan Stratégique National." 2012.

[n] GHESKIO and its partner Cornell University are there to provide technical assistance.
PSI. M&E Plan. 2012

[o] The success of the MSPP/GHESKIO network was due in part to the fact that transport of samples was conducted by NGO personnel on supervision visits for HIV services.
Interview with GHESKIO.

[p] According to the most recent treatment norms, in the case of treatment failure that cannot be attributed to adherence, samples should be taken using a Whatman paper and sent to the LNSP for additional testing. The majority of lab technicians have yet to be trained on the in vivo and in vitro procedures.
CPNMFL. "Normes de Prise en Charge." 2011.

Table 9. Summary of recommendations for attacking the parasite	
Active treatment of positive individuals or foci	• Field test parasite-based attack options, including evaluation of acceptability of different approaches, to select appropriate measures for particular contexts. • Develop new active parasite-based intervention strategy and norms. • Conduct census including complete household mapping and numbering in risk areas. • Increase human resources and capacity to enable implementation of the parasite-based attack strategy. • Design a comprehensive training program in active surveillance and attack for CHWs. • Implement communication campaigns targeted on increasing community acceptability. • Ensure reporting of all activities to centralized database to permit strategic decision-making.
Treatment studies	• Continue chloroquine resistance surveillance and provide refresher trainings for personnel on the protocol in case of suspected treatment failure.
Population movement	• Ensure that health workers report the home location of patients and any travel locations in the previous month. • Work with partners to identify migrant populations intra- and inter-country and target activities in their communities. • Scale up fever-screening activities on the Haiti-DR border.

Strengthening governance and coordination

One of the major strengths of the CPNMFL is its strong political commitment to elimination. The highest levels of the MSPP are also demonstrating interest in malaria elimination. Elimination of malaria by 2020 has been the theme of the last two National Strategic Plans and Bi-national Strategic Plans. However, for these strategies to turn into successful actions toward elimination, a number of managerial and operational obstacles will need to be overcome. The highest levels of the MSPP must be ready to use their political power to quickly resolve roadblocks and ensure that all the different parts of the MSPP play their roles in the process.

PERSONNEL

Elimination is a demanding, complex undertaking that requires a National Malaria Program with a core of dedicated leaders with a clear mandate, authority to demand results, strong program management and technical skills, and available financial and material resources. The program will require personnel in surveillance/M&E, case management, vector control, and communication. The leaders must be able to coordinate the various stakeholders and donors involved in the response to ensure that resources are allocated to priority interventions in focal areas, and that there is no duplication of efforts. Strong departmental teams capable of collecting, analyzing, and reacting to data quickly will be necessary for regional implementation and programmatic flexibility.

Additional personnel at the central and departmental levels are necessary with increased technical and managerial capacity, and these staff must be distributed specifically to regions identified as being high risk for malaria transmission. Key vacant programmatic positions include statisticians, epidemiologists,

mapping specialists, and nurses working in care and treatment. The leadership of the program is currently composed of former members of the SNEM, who may retire before elimination is achieved. Many do not have junior staff on their teams that are learning the technical and management skills that would be required to fill the leadership positions. This would result in a gap in technical knowledge and in management that could threaten elimination efforts. The program should start succession planning immediately and recruit and train personnel with leadership and management experience. Given recent difficulties in hiring and retaining motivated personnel stemming from the loss of salary incentives, the MSPP will need to identify how to make joining and remaining in the program more attractive to potential hires and current staff.

Both current and future staff will require training in new skills; in the short-term, available personnel at central and departmental levels should be trained in the currently missing analytical and medical capacities. Given the role that the CPNMFL will need to play in coordinating the response, training in coordination, project management, financial management and other managerial skills combined with mentorship programs in these skills will aid the program to take on the task of elimination.

The ten departmental M&E officers have been in place since early 2013, but will require additional training on M&E for elimination, particularly in GIS and active surveillance. In addition, only five brigades are operational and seven of the ten departments do not have brigades. The brigades should also be increased in size to support active case detection activities. Adding a GIS expert and a nurse to each brigade would support the brigades in managing activities on the ground.

As discussed in other sections, elimination will require hiring and training a large number of community health workers, brigade workers, or other surveillance agents to conduct active parasite-focused and/or vector control activities. Where possible, current CHWs employed at health facilities or by NGOs can be integrated into the elimination program, but they must be able to dedicate the necessary amount of time to elimination activities and follow the standards and procedures set by the MSPP. Nurses will need to be hired to supervise the workers manage reporting and manage stock distribution from health facilities to community health workers. These nurses can then report to the departmental brigades.

STRATEGIC PLANNING AND COORDINATION

Elimination will require a flexible approach that may vary from region to region, strong accountability to ensure everyone in the program fulfills their roles, and the ability to rapidly respond as circumstances change. Success will require a high level of leadership from the program and from the malaria teams in the departmental directorates in providing direction and coordinating all the actors in each area. The government will have responsibility for aligning all participants around a single vision, set forth in detailed operational plans with clearly delineated roles and responsibilities, as well as widely disseminated and closely adhered to protocols. Operational plans must take into account the varied approaches needed for areas with different levels of transmission, and clearly propose what measures will be used in each area to interrupt transmission. The program also must develop skills in identifying and articulating where there are gaps in coverage so that resources can be re-allocated to those areas. These decisions must be made in collaboration with the departmental directorates and disseminated quickly and widely with health facilities and partners across the country.

A broad range of governmental bodies and NGOs are involved in malaria activities at present, and elimination will require them to work more closely together than ever before. The program has been able to achieve its results to date by working closely with partners and particularly sub-recipients of the GFATM grant. Interviews illustrated that many other organizations and government directorates are

interested in participating more fully in the response and some have even been more involved in the past. In order to increase coordination within the MSPP, the CPNMFL could host malaria-specific planning meetings with other implicated MSPP units to supplement current informal communication across directorates. The program should increase the frequency of information exchanges amongst and joint supervision visits by the DELR, the LNSP and the CPNMFL. More broadly sharing malaria data can increase awareness within the MSPP of the importance of tackling malaria elimination, and regular presentations at the "Salle de Situation" would be an excellent platform for this information-sharing.[q]

The relationship between the CPNMFL and the departmental directorates currently depends on individual relationships and no clear reporting lines, so can vary depending on the department and causes planning and reporting challenges. Engaging more directly with other units such as the DOSS and UADS will help the program in gaining acceptance for the systemic changes necessary in reporting lines from the health departments to the program. The quarterly health department meetings outlined in the National M&E plan occur will facilitate the exchange of information and planning. Different Ministries also work on malaria in an uncoordinated and sometimes *ad hoc* manner. The National Strategic Plan is meant to be multi-sectoral, and efforts to encourage the engagement of and knowledge sharing with the other Ministries can help address challenges beyond the reach of the MSPP. For example, the experience of the Ministry of Agriculture could help target intervention in agricultural areas in the South and Artibonite, where there is expected to be increased risk of transmission. Moreover the Ministry could play a pivotal role in engaging farmers and leaders in these areas. Involving the Ministry of Immigration could help reach migrant populations and the Ministry of Environment could support vector control efforts, drawing on their expertise and data on potential vector habitats to target entomological surveillance. The CPNMFL attends the quarterly GFATM sub-recipient meeting where the principal recipient facilitates an exchange of M&E data. Some departmental directorates also take a leadership role in coordinating the response, bringing partners together for regular regional meetings.

Clear, targeted and coordinated messages about malaria are essential to achieving the coverage levels necessary for elimination, be it for vector control, treatment-seeking behavior or acceptability of active case detection efforts. Community-based actors have the potential to increase the efficacy of the response by increasing health-seeking behavior, strengthening referral, conducting vector control or distributing nets, and building support for elimination.[13] The MSPP should define an expanded role for CBOs and explain how the MSPP will engage them in malaria elimination efforts. Expanding some of these planning meetings to include the private sector and community-based organizations could be a first step to building their awareness of and commitment to malaria elimination.

Organizations doing IEC currently use Ministry-created communication messages or tools or have their own tools validated prior to use. The messages used generally include the importance of going to the doctor if you have a fever/seeking treatment, not self medicating, using a mosquito net, and keeping the area around a house clean.[r] This coordination of messages must continue and the program can provide additional guidance on which messages to prioritize and what mediums to use to increase the effectiveness of IEC at complementing the elimination strategy. The majority of malaria-related IEC done by CHWs and health institutions is limited to regions in which sub-recipients work. The expansion of communication activities should be based on epidemiological analysis and what transmission interruption measures have been selected for the geographic zone. Mobilizing funding to intensify IEC activities in high risk areas and broaden IEC coverage to maintain a baseline level of knowledge or

[q] Departmental "Salle de Situations" were recommended by partners and government officials in the Strategic Plan stakeholder workshop in 2012.

[r] This last message on cleanliness may be more related to LF or Dengue, but CHWs are not necessarily trained on this distinction. Interviews with sub-recipients.

understanding of the risk of malaria in low to moderate transmission areas will support elimination efforts.

Expanding communication coverage at a low cost could be partially achieved through working with the departmental directorates to integrate malaria into other communication activities conducted with CBOs. In some departmental directorates there is an appointed representative for communication who interacts with an extensive network of organizations. The program should work with CIFAS to ensure that malaria communication is part of the regular training curriculum of these professionals and with DSPSE to ensure they are provided with malaria communication tools. The sub-recipients of the GFATM grant as well as organizations such as Zanmi Lasante, work with groups of CHWs identified and hired from surrounding communities.[s] A training workshop should be organized for the current group of personnel.

STRENGTHENING MONITORING AND EVALUATION

Strong M&E throughout the attack phase will be essential to ensure the program is learning from its successes and failures and appropriately adjusting its strategies as elimination progresses. Currently programmatic monitoring is limited, largely donor-driven and not always available to the program.[t] Data is collected on brigade and GFATM-funded activities (training reports, behavior change activity reports, and quarterly reports on GFATM Performance Framework indicators). Reporting to the government on national indicators must be a requirement for all health facilities or organizations conducting malaria-related activities. The CPNMFL should leverage existing financial resources to implement a database for programmatic data at the departmental and central levels). Tools currently in use should be nationalized and new tools and reports for active surveillance and case management quality control/quality assurance reports can be integrated. The MSPP must ensure that NGOs and health facilities are reporting to both CPNMFL and their donors simultaneously.

Currently, PSI's M&E team conducts most programmatic data validation. The CPNMFL's malaria expertise and field knowledge would be well-used in remote data validation and supervision visits at both the institutional and community level. Departmental M&E officers must conduct monthly institutional visits, although this will require additional resources for transport and per diems. However, resources can be saved by coordinating visits with PSI or with other health programs. Departmental directors should play a pivotal role in encouraging such collaboration. CPNMFL and departmental personnel require additional training on effectively analyzing programmatic data with the objective that personnel could compare programmatic and epidemiological data to assess the effectiveness of the response. Additionally, the program would benefit from the introduction of annual program reviews as well as periodic reviews of the success of MDA and MSAT efforts.

STRENGTHENING INFRASTRUCTURE

The CPNMFL recently moved into a new office and has space for expansion in human resources. However, there are still dire equipment needs, which will only be exacerbated by this necessary addition of personnel and intensification of activities requiring more coordination and supervision and higher expectations of surveillance. Available equipment should be inventoried and this inventory compared

[s] In certain cases disruptions in funding have discouraged organizations from having malaria-specific curriculums or community health workers.

[t] As an SR, the CPNMFL is also responsible for reporting to the PR, PSI.
PSI. M&E Plan. 2012.

against the required equipment in order to prioritize needs for elimination. Interviews have suggested the following key needs: cars for the supervision of sites and community level activities; computers for accessing the health information system; and GIS software and PDAs for mapping larval breeding sites. The mobilization of funding for this equipment should occur in parallel with that for additional personnel.

In conjunction with passive surveillance strengthening and implementation of strategic active measures to reduce transmission and cure parasites in the community, it will be critical to build a data infrastructure that can track cases and interventions. The existing HSIS and DSSS databases provide the foundation for this infrastructure, but it must be adapted to allow detailed understanding of where transmission is occurring, whether households in risk areas have been reached by attack interventions, and to direct resources accordingly. This database can comprise the architecture of a decision-support system that can suggest where interventions should be prioritized, where gaps exist, and what progress has been made on the path to elimination.

STRENGTHENING BI-NATIONAL COORDINATION

The sharing of knowledge and coordination of interventions between Haiti and the Dominican Republic is essential, and the program should work to continuously ensure the Dominican Republic's engagement from planning through implementation. Following the completion of the Bi-national Strategic Plan, a technical working group could be created to develop a comprehensive operational plan specifying cross-border activities. This plan would need to include the roles and responsibilities of each government and should be committed to not only by the Ministries, but by donors and technical partners as well. Such a working group could also regularly review and analyze data from the two countries. This group could disseminate quarterly updates on the status of the epidemic across the island.

Table 10. Summary of Program Management and Governance Recommendations	
Personnel	• Recruit and train personnel with a focus on analytical and medical skills, as well as leadership and management experience.
Strategic planning	• Validate and disseminate already drafted Strategic Plans and missing guidance documents to stakeholders. • Improve and ensure more frequent engagement of government, NGOs, the private sector, and CBOs in the response.
Monitoring & evaluation	• Adopt reporting tools, making modifications where necessary for elimination, and requiring reporting from all stakeholders. • Conduct additional supervision of facility and community-level reporting. • Conduct a quarterly stakeholder meeting on surveillance, M&E, and operational research to ensure that lessons learned are shared and that there is no duplication of efforts.[u] • Create analysis tools that consolidate programmatic and entomological research with medical surveillance data to determine whether interventions are working.
Infrastructure	• Mobilize the resources required to equip both the existing and new personnel for an elimination campaign. • Construct a data system to permit detailed analysis of progress and gaps.
Bi-national cooperation	• Facilitate an exchange of data between the DR and Haiti. • Encourage bi-national operational planning and coordinated implementation.

Planning to maintain elimination

Once malaria has been eliminated from Hispaniola, as long as anopheline mosquitoes exist there will continue to be a risk of reestablishment of transmission from imported cases. Additionally, aiming for but failing to achieve elimination will create the possibility of disease resurgence[5]. Programmatically, this means that the island must always maintain the capacity to manage the transmission risk that will continue to exist. Planning for this maintenance program is important to ensure buy-in from donors and high levels of the government that malaria will remain a threat even after elimination is achieved.

Haiti and the DR will have to weigh the risks of resurgence against the costs of continued activities against malaria post-elimination. Based on information from the Dominican Republic, it appears that importation rates from outside Hispaniola are low, and these activities can likely be minimal as long as a strong surveillance program remains in place. Maintaining a small coordinating central body may be appropriate during the post-elimination phase. The body's role would focus on maintaining the surveillance system in continuing to focus on testing for malaria in high risk locations, ensuring that appropriate supplies are purchased and distributed to enable outbreak response, and dispatching human resources to investigate and resolve potential malaria cases as they occur. It could also continue to play a role in ensuring that diagnosis, treatment and surveillance standards are up to par with international standards.

As this unit will be very small, it is essential that the government also ensure that some activities for malaria outbreak response is integrated into the general health system. For example, messages on treatment-seeking for fevers can be integrated into more general public health messages and

[u] Successful examples can be found in HIV, where there is an M&E cluster and Surveillance stakeholder working group.

community health workers' standard training can include a module on malaria case management. All clinical personnel should continue to receive basic training in identifying malaria cases and performing rapid tests. A stock of rapid tests, chloroquine and primaquine, and some vector control supplies must remain available throughout the country in case of suspected malaria. Both countries should also maintain malaria-related indicators in the surveillance and reporting systems. Keeping at least one rapid response team in the country, capable of conducting passive case detection and vector control, would allow potential cases to be investigated quickly and transmission interrupted before resurgence can occur.

Table 11. Summary of Resurgence Recommendations

Resurgence	• Maintain a small core central unit responsible for malaria; • Continue to distribute testing, treatment and vector control supplies to health facilities; • Ensure health workers continue to be trained on malaria case management; • Seek opportunities to integrate vertical activities into the general health system; • Maintain a rapid response team to investigate and deal with malaria cases.

Current financing

Figure 26 illustrates funding sources for malaria-specific activities conducted by the MSPP and its partners.[81] The Round 8 Phase II GFATM grant to Haiti is the primary source of funding to the malaria program, accounting for approximately three quarters of the US$13.7 million committed in 2012. Over the next three years, the grant is scheduled to contribute approximately US$7 million a year. The Haitian government contributes over US$2 million a year to the malaria program, or about 18% of the investment in malaria in 2012. Additional support is provided by the CDC and PAHO, though the magnitude of future funding from these donors is not known. Individual projects are funded by the Carter Center and Gates Foundation (mainly for LF), as well as partners such as Zanmi Lasante, though precise budgets for these projects is not tracked at a national level and was thus not included here.

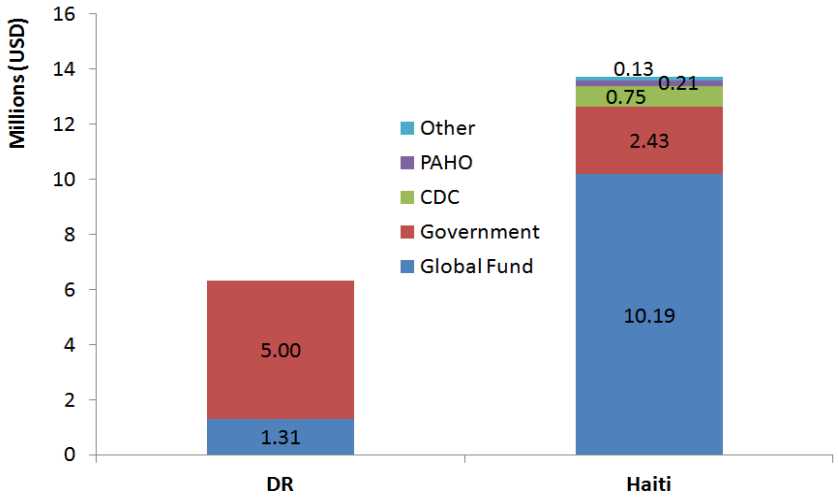

Figure 26. Comparison of funding distribution by source for the DR and Haiti in 2012.

The Dominican Republic's 2012 budget was approximately US$6 million. As shown in Figure 26, the Government of the Dominican Republic contributes 80% of all funding in the country. However, the Dominican Republic benefits from a GNI per capita 8 times higher than that of Haiti, as well as assistance from the agricultural and tourism sectors. There is no guarantee that this level of funding will be maintained in the DR, particularly given that the current DR GFATM grant ends in 2014 and the new GF funding framework focuses on lower-income countries with a high prevalence, excluding the DR from all but regional elimination initiatives. Moreover, even if funding from donors was secured, experience in Haiti and across the developing world shows that Official Development Assistance (ODA) is extremely volatile, which can jeopardize the success of an elimination effort.[82]

To examine budget requirements under the current program as well as various elimination scenarios, a model budget was constructed. The budget included a full array of expenditure categories including salaries, trainings, commodities, research expenses, and operating costs. In general, the annual costs of Haiti's current malaria program consist primarily of:

- Passive surveillance and case management costs, primarily consisting of expenditure on blood tests and drugs (approximately US$1.1-US$1.5 million per year). Salary costs for healthcare workers at health facilities were not included in this tally as they would be borne by the government even in the absence of a malaria program;
- National program costs, including salaries, infrastructure, and equipment for the national malaria program (approximately US$1.2 million) as well as the local NGOs that support it and help implement GFATM-supported programs (approximately US$2.9 million);
- General M&E and research costs (approximately US$250,000).

These baseline costs total approximately US$6 million per year.

In addition, a current accounting of the malaria budget might include the cost of conducting bed-net distribution campaigns. Nets were first introduced under Haiti's Round 3 grant, with free distribution beginning in 2008. The Round 8 grant distributed 2 million nets, with a budgeted cost of approximately US$14 million. Distribution occurred in 2012 across Haiti. Continuing with such a strategy would require periodic redistribution to known risk areas of the country, requiring substantial recurring costs during the campaign year. Approximate expenditure under continuation of such a program is depicted in Figure 27.

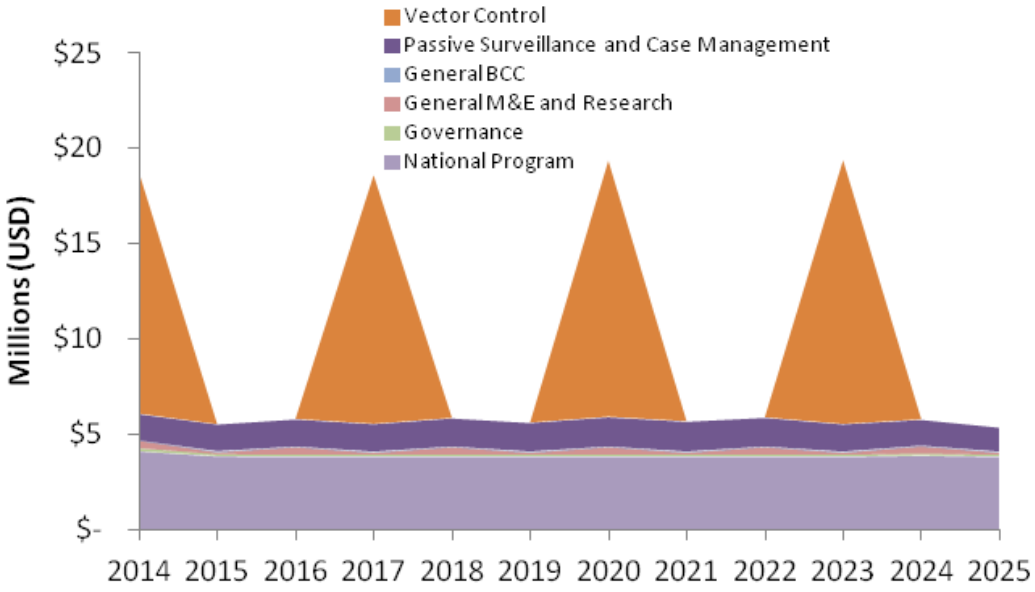

Figure 27. Ongoing costs of the current malaria strategy.

Costing elimination

Conducting a precise costing of what will be required for an elimination campaign will not be possible until a detailed strategic plan is agreed upon. Nevertheless, it is useful to consider the magnitude of what will be required to achieve elimination based upon the technical and operational requirements described in this report.

We consider two scenarios here to understand what elimination costs might look like under different feasible strategic options.

1. In the first scenario, Haiti implements an elimination program focused on identifying high risk foci through a combination of strengthened passive and reactive case detection. In this hypothetical program, the entire population of identified high risk foci is given a treatment that includes primaquine to drain the reservoir of infection. We cost both the current CQ-PQ regimen, and as an alternative, compare that cost to that of using an ACT with PQ instead. Per the technical assessment, such a campaign should be sufficient to eliminate malaria within five years if 95% coverage of the population is achieved with three rounds of treatment each year.

   Based on the risk map presented earlier in this report, we estimate the population to be targeted to number 2.2 million people, and we assume that this population is distributed in communities of 10,000 people each. To be conservative, we further assume that all of these communities are linked by human mobility and must therefore receive interventions at the same time. Vector control – in the guise of larviciding, fogging, or indoor residual spraying – is also conducted in high risk locations to protect against transmission from any missed infections. We assume that passive surveillance strengthening occurs using existing resources, and additional funding beyond the base case described above are not included in this scenario.

   The results of this costing scenario are depicted in Figure 28.

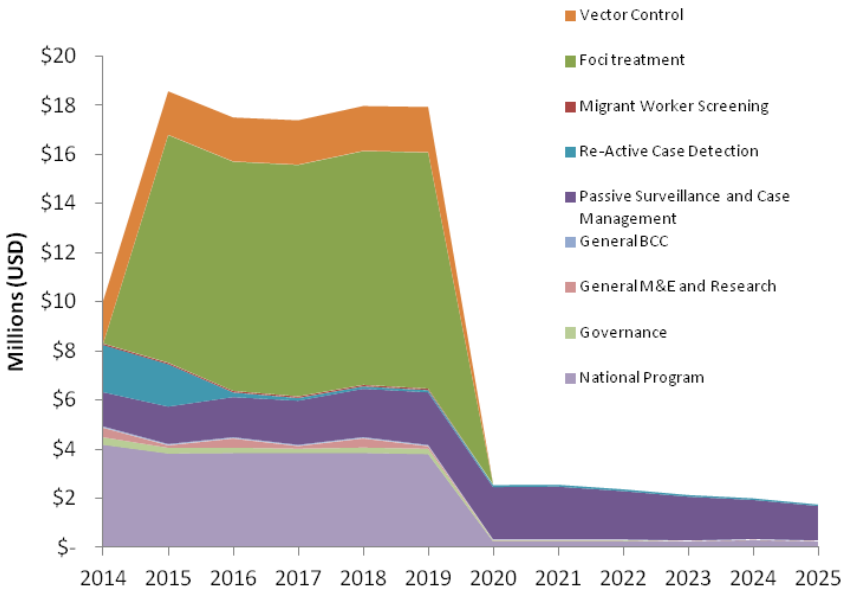

Figure 28. Programmatic cost breakdown for a scenario in which elimination is achieved by treating populations within high risk foci.

Total costs for this scenario run approximately US$18M a year over the five years in which chloroquine and primaquine are used to treat the populations in the identified high risk foci. If ACTs are substituted for chloroquine, annual costs increase to over US$25M. Elimination is achieved by 2020 and costs are substantially reduced thereafter as the program reverts to testing febrile clinical cases and managing risk. The total costs for the period 2014-2020 run approximately US$102M-US$146M.

Unsurprisingly, the largest cost driver is the administration of drugs to the high risk foci. These include both the cost of the commodities themselves as well as substantial communication costs to ensure communities understand the goals of intervention and are comfortable participating. Costs are broken down by budget category in Figure 29.

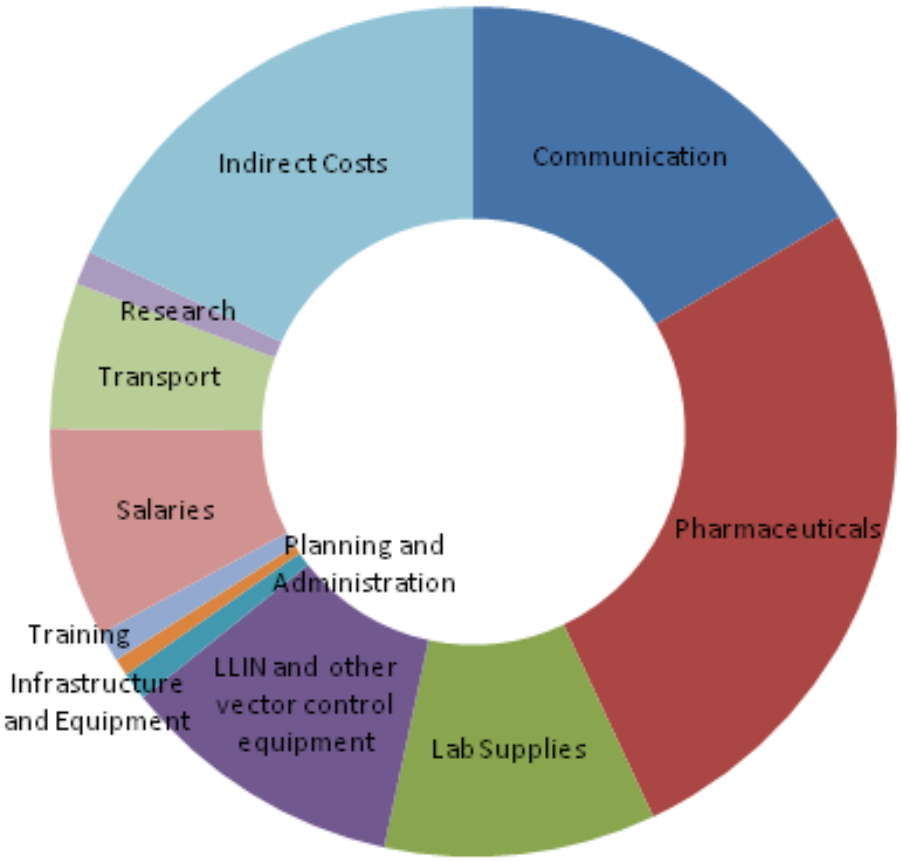

Figure 29. Total budget by category for a scenario in which elimination is achieved by treating populations within high risk foci.

These costs potentially could be substantially reduced if populations in targeted foci can be defined more specifically than has been done here; as more robust surveillance data become available, better maps can be made that more precisely define which populations must be targeted. In addition, it is possible that not all foci must be simultaneously attacked: if certain foci are responsible for exporting infections to other foci, targeting efforts to those source foci could greatly reduce costs. Defining these connections between foci will require improving the mobility analysis presented in the technical assessment of this report.

2. A second hypothetical scenario suggested that Haiti might implement a program focused on testing the entire 2.2 million people believed to live in high risk foci and treating anyone who tests positive. Three rounds of testing and treating would be conducted each year for two years. As with the prior scenario, it is plausible that many fewer people could be tested if more specific maps of malaria risk are made. This individual-based treatment will be sufficient to interrupt transmission in low risk regions, but the technical assessment suggests it may be insufficient to do so in higher risk regions (field trials will be required to verify whether this suggestion is

accurate). However, the widespread testing will provide excellent data for refining risk maps. In the following years, this scenario suggests that the full populations of the highest risk foci would then be treated as in scenario 1. We estimated the required budget to do so if 300,000 people live in these highest risk foci and assume that 95% of the population will be treated in three rounds of drug distribution each year for three years. As in scenario 1, we assume that passive surveillance strengthening occurs using existing resources, and additional funding beyond the base case described above are not included in this scenario.

The results of this costing scenario are depicted in Figure 30. Total costs for this scenario would be estimated to peak at approximately US$23M a year for the two years of the campaign when the populations of all at-risk areas are being tested with rapid diagnostic tests. Costs are substantially reduced to only about US$10 million a year after the campaign switches to treating the highest risk foci, and will decline further after elimination is achieved in 2020. Total costs for the period 2014 - 2020 run approximately US$88 million.

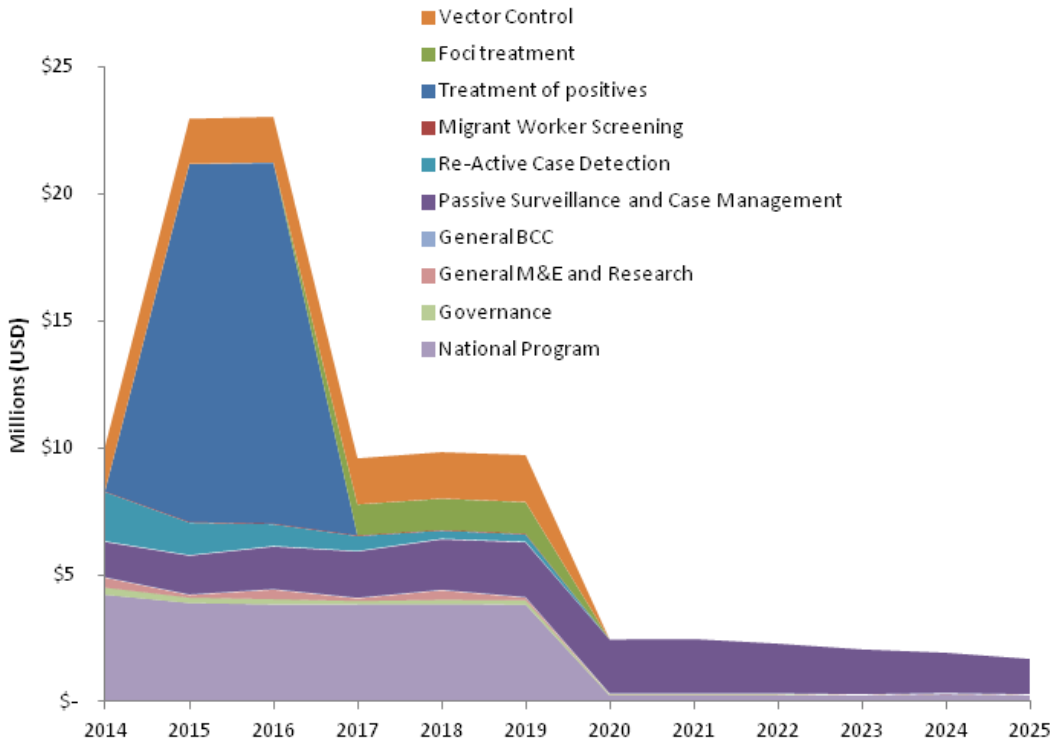

Figure 30. Programmatic cost breakdown for a scenario in which elimination is achieved by first testing and treating populations within risk areas, followed by treating the entire population within the highest risk foci.

Costs under this scenario are initially higher than the first scenario due to the fact that rapid diagnostic (or RDT)?? tests are more expensive than treatment. However, once the highest risk areas are well defined, costs decline as the program concentrates on draining the parasite reservoir within these foci. Figure 31 shows the elimination budget for this scenario by budget category. Costs for rapid diagnostic tests are the largest expenditure under this scenario.

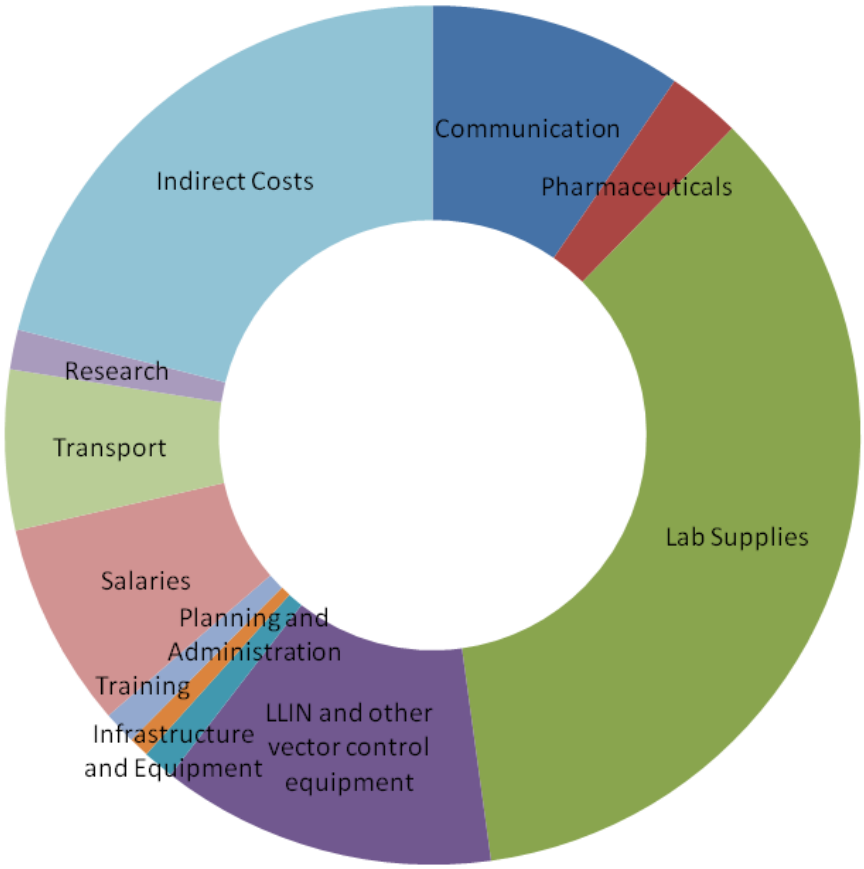

Figure 31. Total budget by category for a scenario in which elimination is achieved by first testing and treating populations within high risk foci, then treating everyone in the highest risk foci.

Both of these scenarios are rough approximations and may not be indicative of the strategy the Haitian government will choose to eliminate malaria. The budgets of each could potentially be reduced if better surveillance data allows for more precise risk mapping, and improved understanding of how parasites move throughout Haiti permit the program to target places that export infections. These estimates may thus be conservative, and actual budgetary requirements could be lower. Nevertheless, the hypothetical budgets described here suggest the government should consider the feasibility of securing approximately US$100M to enable a successful elimination campaign by the target date of 2020. Given the national population of 10 million people, such an expenditure would work out to about US$10 per person, or US$15 per person at risk.

Efficiency and effectiveness

Elimination will be an expensive investment in the short to medium term, but viewed over the longer term there is the potential to reap cost savings. More detailed analysis based on robust field assessment of transmission risks and quantification of the malaria importation rate from other endemic countries will be required to quantify precisely what long-term expenditure may be required. Nevertheless, available data suggest the risk of malaria resurgence after elimination will be quite low. Haiti does not yet categorize malaria cases as to whether they are imported or locally-acquired, but the source of infection is determined during case investigations in the Dominican Republic. Data were available on the number of locally-acquired and imported malaria cases for the first four months of 2011, 2012, and

2013. As depicted in Figure 32, only one malaria case was identified as having been imported from a country other than Haiti in the first four months of 2011, three in 2012, and five in 2013. If importation rates are similarly low into Haiti, it seems likely that little investment will be required to maintain malaria elimination as long as surveillance is sufficiently strong to identify and treat those cases that do migrate to the island.

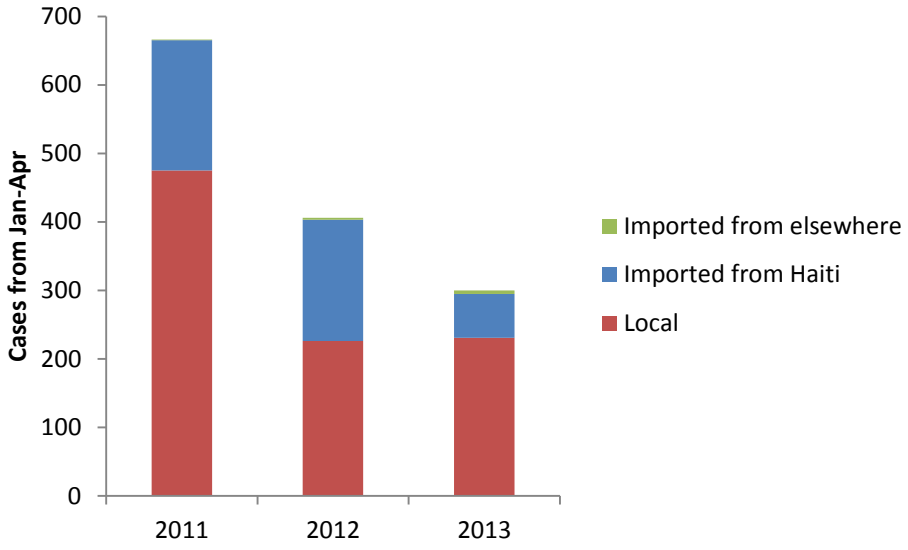

Figure 32. Number of malaria cases resulting from local transmission, imported from Haiti, or imported from elsewhere identified in the Dominican Republic during the first four months of 2011-2013.

If analysis suggests ongoing risk of resurgence can indeed be managed through the general surveillance system, the current high rates of expenditure on malaria control could largely be halted. Doing so would then make eliminating malaria a sensible financial decision for the long-term. Current control strategies are costing approximately US$6 million a year for passive case detection and maintaining the program, and distribution of nets cost well over US$10 million in 2012. Assuming US$10 million is required for vector control every three years, annual costs of continued control would be approximately US$9.3 million a year; if nearly all of these costs can be halted after elimination, a US$100 million elimination campaign would pay for itself in just over a decade in direct costs alone.

In addition, successful elimination would generate many indirect benefits. Eliminating malaria will lessen the burden on the public health system, allowing Haiti and the DR to concentrate on other health priorities. Malaria has been demonstrated to have substantial impact on other causes of morbidity and mortality, meaning that reductions in malaria may have a bigger impact on all-cause disease than would be expected based on malaria incidence alone.[83] The potential for outbreaks and resurgence in other Caribbean countries could be averted, along with the costs required to avert them. And initial suggestions that the parasite may be becoming resistant to chloroquine significantly suggest that elimination today may be substantially cheaper than in the future. While a formal cost-effectiveness analysis has not been conducted as part of this feasibility study, qualitatively weighing the costs described above against the public good of eliminating malaria in the Caribbean demonstrates long-term health and economic gains for the island.

The costs of elimination may be justified, but securing sufficient donor funding to achieve it will require devising a highly effective, optimized campaign that directs resources in a targeted way. Allocative

efficiencies should be promoted by regular monitoring of the efficacy of interventions and targeting of the most effective interventions towards the areas of greatest need using a risk map. Understanding exactly where malaria parasites are in Hispaniola and how they move may suggest optimal strategies for eliminating them without resorting to blanket coverage of the entire population. Research and analysis that would help describe such strategies may thus be an important investment that can reduce overall costs.

There are also additional opportunities to improve administrative and technical efficiency. Doing so could include any of the following examples.

- *Grant structure*: Reduce the number of recipients of a grant, rely on more government or local organizations, and coordinate activities to reduce overheads.
- *Coordination across countries*: Contract one consultant to create an automated case reporting database needed in both Haiti and the Dominican Republic. This will reduce otherwise duplicative overheads, while benefiting the programs by automating an information exchange.
- *Coordination across projects*: Integrate the malaria supply chain with other diseases. For example, RDTs could be partially distributed through the HIV supply chain in Haiti, which reaches most regions of the country. This would again ensure both efficacy and a reduction in overheads that come from a fragmented system.
- *Coordination across disease areas*: Implement the WHO recommended IVM strategy for malaria, LF, and dengue fever where there is geographic overlap of transmission. Nets and fumigation can be effective in preventing all three diseases, and by integrating the disease strategies, the cost to the health system for each infection averted would decline.

During the phases of elimination and prevention of reintroduction, expenditures should be tracked and compared against outcomes, in order to determine and prioritize areas for increased efficiency.

Financing to maintain the gains

Once the number of cases is reduced to or near zero, other priorities come to the forefront and donor funding will only decrease and funding volatility will increase. A recent literature review identified 75 resurgences in 61 countries from the 1930s-2000s, and in over 90% of cases, resurgence was attributed to a weakening of programs, with over half of this weakening being attributed to funding constraints[5]. There is therefore a need to examine long-term, stable financing that is dedicated to the government preventing reintroduction of malaria or outbreaks during the post-elimination phase. This section considers potential options for both securing existing financing and additional revenue generation.

ENDOWMENT/TRUST FUND

Current donors that might otherwise withdraw from the response after elimination should consider a one-time seed grant for an endowment or trust fund, to ease their withdrawal. For example, in the 1980s USAID set-up many endowments in Latin America and the Caribbean, perhaps the most successful of which is the Profamilia endowment in Columbia, which was funded to ensure health facilities continued to be upgraded after the withdrawal of a USAID mission.[v] Donors might be more willing to commit to this mechanism if the government contributed as well. In addition, including private investors in a blended capital endowment would ensure additional stability. Private investors such as hotels or even corporations owned by Haitian Diaspora oversees, could have a mechanism by which they invest

[v]Horkan and Jordan, USAID (1996). "Endowment as a Tool for Sustainable Development." and Lane and Glassman 2008.

money and collect only a percentage of the interest, contributing the remainder to the response. Similar efforts to include the Diaspora in development can be seen in the recent USAID and Foundation Sogebank investment project, the Haitian Diaspora Marketplace; a cost-sharing mechanism launched to allow a contribution of the Diaspora to local business. Even with the private sector involvement, disbursements from interest on an endowment would still be vulnerable to market conditions, so there should be a way of supplementing interest income in down years. For example, the Tuvalu Government endowment has ensured a portion of the investment income earned in up years is re-invested in the fund and can be drawn on in years when investments fall short.

EMERGENCY DEBIT FUND

Some donors may be uncomfortable with an endowment dedicated to malaria, particularly if other priorities may seem more pressing. Before considering withdrawing altogether, they should be encouraged to consider an emergency debit fund only for the prevention or control of outbreaks. Certain portions of this fund could be lent out for other purposes as long as donors guarantee that the country always has a certain level of funding available. The government could also be required to meet conditions such as good management of funds in order to withdraw money. It is recommended that multiple donors co-finance this fund or that a regulatory body be charged with ensuring donors meet their commitments, to ensure sustainability.

HYPOTHECATED TAXES AND FUNDRAISING

While debit funds and endowments can be seen as securing donor funding, taxes and fundraising will be key in providing additional funding. Progressive taxes are suggested based on the success of the UNITAID model, which uses revenues from an airline ticket tax to purchase medications for HIV, TB, and malaria. This tax is progressive, relatively stable, and earmarked so as not to be re-allocated to competing priorities. The countries could consider adding, or in the case of the DR augmenting, a tourism tax in order to raise revenue to contribute to the response. Many countries implement a tax upon entry and this has not affected tourism. While Haiti's tourism is currently limited, there are recent efforts to improve this, which could be met with a small fee to provide for elimination efforts. Moreover such taxes would benefit from development workers and Haitian Diaspora visiting the country, which as a group, have an interest in malaria elimination.

Another potential tax is that on Diaspora remittances. There are currently millions of Haitians living abroad. In 2010, the Migration Policy Institute estimated US$ 1.5 billion in remittances to Haiti and growing, with the majority coming from Haitians in the US and France.[w] This tax however, might affect the willingness and ability of Haitian Diaspora to send remittances. Additional polling or research is required. In the interim, a separate fundraising effort could target the Diaspora and other affected individuals and industries. This could be as simple as setting up a website through which people could contribute to the elimination response and following up with advertising on planes to and from Haiti and the Dominican Republic. Annual revenues from these taxes or fundraising efforts would be disbursed regularly or kept in an investment fund that could be drawn on as needed but that is earmarked for malaria.

[w] http://www.migrationinformation.org/datahub/remittances/Haiti.pdf

REGIONAL FUNDING POOL

Like taxes, a regional pool mechanism suggests changing the donor base. A regional pool would include countries that would benefit from malaria elimination in Haiti, whose investments might then be more secure. There are many countries with a financial, public health, or political interest in elimination in the Caribbean. For example, being able to say the Caribbean was free of malaria may increase tourism to the region. Moreover, it may prevent real losses as in 2008, the Dominican Republic estimated a US$200 million loss in revenue from tourism due to an outbreak of malaria.[x] While domestic financing from the Dominican Republic will be required to maintain border screening and surveillance, other Caribbean middle income countries have similar stakes in elimination and could contribute to Haiti's response. In addition, nearby countries such as the United States, which has the highest concentrations of Haitians living abroad, would stand to gain from elimination.[y] Contributions to a regional pool could come from governments but also private foundations and affected industries. Contributions to a regional pool of funding could be conducted annually and managed by a regional or international body such as the Caribbean Community (CARICOM). This regional body would be required to penalize poorly performing donors by requiring additional funding the following year for example, and therefore ensuring stability.

[x] International Task Force for Disease Eradication. Eliminating Malaria and Lymphatic Filariasis from Hispaniola. 2009.
[y] There were 546,000 Haitian immigrants in the US in 2008. US Census Bureau (2008)

CONCLUSIONS

The feasibility – and the challenge – of malaria elimination in Hispaniola is underscored by the very near success of "eradication" efforts in the 1960s. The DR succeeded in reducing the number of malaria cases to only 21 cases in 1968, while Haiti reduced slide prevalence rates to well below 1% despite testing over 1 million people that same year. These gains were not sustained however: financing proved insufficient, and Haiti's mass drug administration program appears to have been designed with insufficient consideration for managing reintroduction by mobile populations. Despite localized success in interrupting transmission, national implementation was insufficient to consolidate these gains, and malaria resurged throughout the 1970s. Faced with persistent imported malaria from Haiti, the DR was also eventually overwhelmed. Learning from what worked and what failed in the previous elimination efforts will be important as Haiti and the DR design contemporary implementation plans to achieve elimination by 2020.

The 2012 number of malaria cases (952) in the DR was the lowest since 1997 and suggests that the increasing trend in malaria cases that occurred there throughout there much of the last two decades may have been reversed. The program consists of a mix of vector control for prevention and case detection and active follow-up. In Haiti, recent prevalence and slide positivity rates have been substantially lower than historically reported; a population-representative survey detected parasite prevalence <1% in 2011. Current efforts have involved distribution of insecticide-treated nets, supported by the GFATM, while partners including local NGOs and the US CDC are working to improve surveillance systems.

The DR demonstrated the technical feasibility of interrupting transmission in the great majority of the country in the 1960s, although it was unable to maintain elimination given continued importation from Haiti. Accordingly, this assessment focused on evaluating the prospects for Haiti to eliminate malaria under the assumption that success in Haiti will be the key to long term sustainable elimination across Hispaniola. Results suggest that the bi-national goal of malaria elimination from Hispaniola by 2020 is technically feasible. Achieving it will require achieving very high coverage with attack measures, likely including both treatment and vector control, in the transmission foci where malaria prevalence remains high. Initial mapping suggests one fifth of Haiti's population may live in such foci, but improved understanding of malaria epidemiology will be critical for elimination efforts and will depend upon nationwide strengthening of passive and active surveillance activities. Simulation models predict that vector control alone will be insufficient to achieve elimination, but field trials of other measures, such as treating populations within defined risk foci with a treatment including primaquine, will be required to define optimal interventions for specific contexts in Haiti.

Substantial operational constraints exist to elimination in Haiti. Programmatic realignment and support from partners will be required to strengthen and reorient the current control program towards elimination. Three broad areas in which operations must be strengthened were identified: first, stronger surveillance systems to identify, treat, and swiftly report malaria infections, including both passive and active measures, must be put into place, and means of using these systems to direct elimination activities must be devised; second, anti-malaria interventions, potentially including both vector control and parasite-focused measures, must be targeted in an evidence-based way towards specific transmission foci, and organizational and logistical systems must be constructed that can facilitate scale-up to sufficiently high coverage levels; third, the government's capacity to lead and coordinate the elimination program must be improved, and more detailed plans for how an elimination program is to be conducted and monitored by the government and its partners are required. Conducting the sort of

parasite-based testing and treatment campaigns suggested by the technical assessment will require a substantial program of community outreach to ensure acceptability and compliance, and a great expansion in malaria staff and organization will be required to carry them out; the experience of ongoing mass drug administration efforts for lymphatic filariasis suggest that doing so will be possible if challenging.

Draining the parasite reservoir in all transmission foci, potentially involving >2 million people, will be costly and will require new donor commitments. On the other hand, costs are estimated to fall dramatically after elimination is achieved because importation of new malaria infections from abroad is likely to be very low. Nevertheless, some ongoing costs will be required to maintain strong surveillance and ensure that malaria transmission is never reestablished; the recent example of cholera reintroduction illustrates the potential danger. The analysis described here suggests elimination may prove net cost saving within a decade, a far more optimistic result than has been suggested for countries in other contexts where substantial investment is assumed to be required even long after elimination is achieved.[84]

The analyses presented here have numerous limitations. The initial risk map presented here is based on positivity rates reported by a subset of health facilities. Inconsistent definitions of the denominator, "suspected malaria" are likely to influence results, as are spatial patterns in blood testing rates across Haiti; additionally, the map assumes transmission occurs at the location of the health facility since no information on patient household location is available. Refinement of these maps should occur in partnership with the CDC, which is working on the ground to strengthen and expand this system, to understand caregiver interpretation of case definitions; implementation of active follow up to geo-locate patient households will greatly improve the accuracy of future maps. Results of simulation modeling are very sensitive to a few assumptions; in particular, results depend upon the size of the community being modeled. In small communities of only a few hundred people, simulations suggest parasite-based attack measures are much more likely to successfully eliminate malaria than in large communities of many thousands of people. More precise surveillance data will be required to understand the true population sizes of high risk foci and thus the probability of success through such a treatment campaign. Budget estimates for the hypothetical elimination programs outlined here are very rough, and true costs will depend upon the precise plan devised by the malaria program. Additionally, we have based costs upon the assumption that the estimated >2 million people living in areas of moderate to high risk must be targeted simultaneously to achieve elimination. In reality, a spatially progressive approach involving intensive but staged attack may permit cost savings. The actual populations living in risk areas must be determined more precisely as better surveillance data become available.

Nevertheless, this assessment suggests that malaria elimination is technically feasible in Hispaniola by the target year of 2020 if substantial resources can be devoted to strengthening the malaria program in Haiti and reorienting it towards elimination. Determining what interventions will be most effective at achieving it will require testing and evaluating a variety of different strategies in different transmission contexts; supporting the government in conducting such trials soon will be critical for ensuring the malaria programs can devise specific implementation plans based upon a strong evidence base. Surveillance strengthening, including ensuring all fevers are tested, treated, and reported appropriately at health facilities, is also essential to improving knowledge about where malaria occurs and at what intensity across Haiti. Ensuring existing funding from the GFATM is used effectively to help prepare for elimination should be a high priority. Haiti has many partners already supporting anti-malaria activities; their coordination and support to the ministry of health will be crucial as Hispaniola moves towards elimination.

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