An investment case for preventing the reintroduction of malaria in Sri Lanka

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Cover photo: From atop a watch tower in Sigiriya, Sri Lanka, a rural youth keeps a vigil under a mosquito net to save his family's crops from possible attacks by wild elephants. © 2015 Debdatta Chakraborty, Courtesy of Photoshare

Back cover photo: Mihintale peak, Anuradhapura, Sri Lanka. © 2015 Anton L.V. Avanceña

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Contents

Key terms and acronyms

ACD	Active case detection
APCD	Activated passive case detection
AMC	Anti-Malaria Campaign
CSR	Corporate social responsibility
D	Diagnosis
GDP	Gross domestic product
Global Fund	Global Fund to Fight AIDS, Tuberculosis and Malaria
IEC	Information, education, and communication
IP	Inpatient
IPTp	Intermittent preventive treatment in pregnancy
IRS	Indoor residual spraying
LLIN	Long-lasting insecticidal net
ME	Monitoring and evaluation
MOH	Ministry of Health, Nutrition and Indigenous Medicine
NMSP	National malaria strategic plan
OOP	Out-of-pocket
OP	Outpatient
PCD	Passive case detection
PM	Program management
POR	Prevention of reintroduction
PVC	Prevention and vector control
RDT	Rapid diagnostic test
RMO	Regional malaria office
ROI	Return on investment
SEM	Surveillance and epidemic management
SM	Severe malaria
SP	Sulphadoxine pyrimethamine
TP	Treatment and prophylaxis
UCSF	University of California, San Francisco
ULY	Useful life year
UM	Uncomplicated malaria
USD	United States dollar
VLY	Value of life year
WHO	World Health Organization

Executive summary

Sri Lanka has had no locally transmitted cases of malaria since October 2012 and no indigenous deaths since 2007. However, these successes are being challenged by sustained receptivity and vulnerability to malaria, declining financial assistance from external donors, waning political interest to tackle malaria, and competing national health priorities.

The purpose of this study is to develop an investment case for prevention of reintroduction (POR) of malaria in Sri Lanka that can be used by the Anti-Malaria Campaign to advocate for sustained financial resources.

A micro-costing of Sri Lanka's malaria program was carried out in early 2015 to estimate the cost of current POR activities. The cost of malaria resurgence—which, when averted, represents the potential benefits of investing in malaria POR—was estimated using a hypothetical scenario generated based on historical epidemiological data. These estimates were used to compute the return on investment (ROI) of malaria POR. The time frame for the analysis in this study was six years (2015–2020).

An estimate of the total cost to keep Sri Lanka malaria-free was approximately USD 11.9 million or USD 0.57 per capita per year. The major cost driver of the current POR program was human resources. Among all interventions, program management, surveillance and epidemic management, and diagnostics constituted the highest proportion of costs.

Investing in malaria POR in Sri Lanka generates a median ROI of 13.3 to 1. By preventing resurgence, malaria POR results in major cost savings to the national and district malaria programs and the larger health system, as well as economic benefits to the Sri Lankan economy.

Introduction

This report presents an investment case for preventing the reintroduction of malaria in Sri Lanka developed by the Global Health Group of the University of California, San Francisco (UCSF) in partnership with the Anti-Malaria Campaign (AMC) of the Sri Lanka Ministry of Health, Nutrition and Indigenous Medicine (MOH). As part of the investment case, UCSF Global Health Group assessed the current and future costs of keeping Sri Lanka malaria-free and estimated the economic returns associated with avoiding future malaria resurgences.

Sri Lanka has made extraordinary gains in reducing the burden of malaria in the last decade. Between 2000 and 2011, the number of annual malaria cases declined by more than 99%, from 210,000 to 124.[1,2] With no locally transmitted malaria cases recorded since November 2012 and no indigenous deaths since 2007, the AMC is in the process of malaria-free status certification with the World Health Organization (WHO).[1,3] This period of progress in malaria control in Sri Lanka is associated with steadfast political and financial commitment from the government and financial contribution from donors, particularly the Global Fund to Fight AIDS, Tuberculosis and Malaria (Global Fund).

With its success in interrupting local malaria transmission, Sri Lanka has shifted its focus from malaria elimination to prevention of reintroduction (POR), which brings new programmatic and financial challenges.[4] Global Fund support for malaria elimination, particularly in middle-income countries such as Sri Lanka, is declining due to a focus on malaria control in low-income and high burden countries.[5] Political interest in malaria is waning as other health issues such as dengue fever and non-communicable diseases become more prominent.[4] Awareness of malaria among health workers is also declining, as the disease is no longer seen as a public health threat.[4] However, losing focus on malaria after effective elimination efforts may risk the gains Sri Lanka has made in the last four decades. Historical accounts show that withdrawal of funding and scaling down of malaria efforts are associated with malaria resurgences in Sri Lanka and other settings.[6]

Background and context

Sri Lanka is divided into three climactic zones: a wet zone in the southwest, an intermediate wet zone in the northwest and west, and a dry zone in the north, east, and southeast. Historically, malaria has been endemic in the dry and intermediate wet zones, with little to no malaria in the southwest region, due to copious rainfall.[1] Sri Lanka has a long history of malaria control, with periods of success punctuated by resurgences (Figure 1).[7,8] In 1934–1935, the largest malaria outbreak in the country took place, causing 5.5 million malaria cases and 80,000 deaths.[1,2] The epidemic was largely controlled through the use of larvicides and antimalarials.

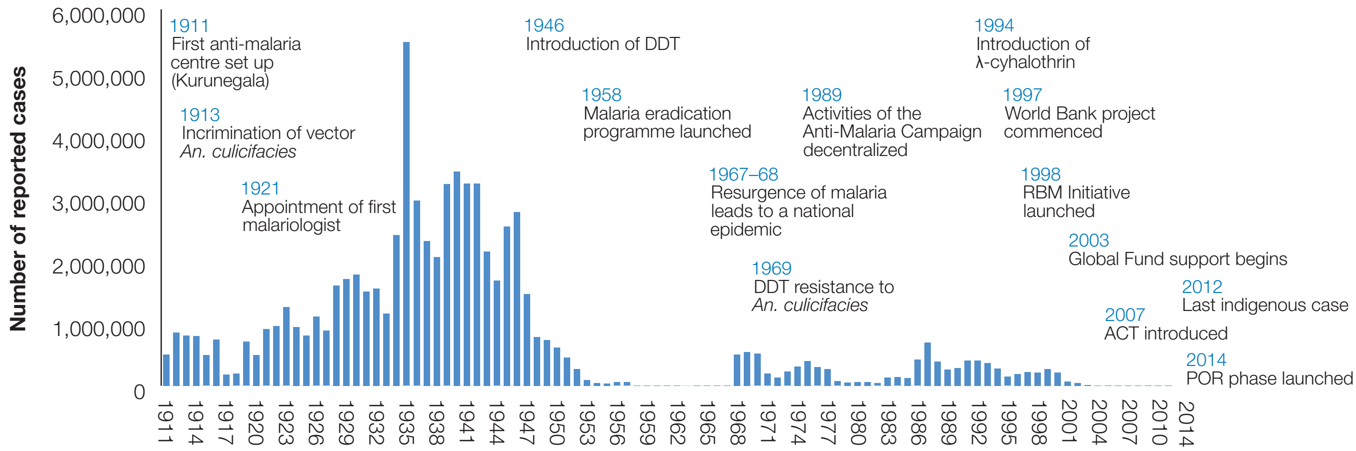
In 1945, an extensive indoor residual spraying (IRS) operation was launched. The early success of IRS in reducing the malaria burden compelled the country to embark on a malaria eradication strategy in 1957, coinciding with the WHO's Global Malaria Eradication Programme. By 1963, malaria elimination was on the horizon with only 17 cases reported in public facilities, of which only six were indigenous. With this success came a severe cutback in political and financial support for malaria control, leading to the withdrawal of malaria control measures such as IRS and a weakening of surveillance systems. What followed was rapid resurgence with an enormous increase in confirmed malaria cases—reaching a peak of 537,705 cases in 1969.[9] Between 1970 and 1999, the AMC resumed malaria control interventions; however, frequent epidemics occurred during the 1980s and early 1990s, and total annual cases remained well over 100,000. The most recent serious epidemic took place in 1986–1987, with 56 reported cases per 1,000 persons in malaria-endemic areas.[1,2] During this epidemic, 70% of the reported cases were from the Northern and Eastern Provinces of Sri Lanka where the Sri Lankan civil conflict was largely concentrated.[10,11]

Between 1999 and 2008, reported cases and deaths declined more than ten-fold to 196 confirmed cases and zero deaths.[1,2] Between January and September 2012, there were 24 indigenous and 70 imported malaria cases, but since October 2012, no indigenous malaria cases have been reported.[4] The end of the civil conflict in 2009 and implementation of intense malaria control activities, together with close monitoring and evaluation of interventions, are considered pillars to the achievement of zero malaria cases.

Despite remarkable achievements in malaria elimination, Sri Lanka faces a significant threat of resurgence in areas of high receptivity[a] characterized by increased travel, tourism, and the arrival of immigrants. In 2013, 95 imported cases of malaria were reported sporadically throughout the year that did not follow seasonal patterns observed in the past. Sixty percent of the imported cases occurred among Sri Lankans returning from travel, and most of them were diagnosed and reported by public sector hospitals in the Western Province, an area not traditionally endemic to malaria. Only a small fraction of these imported cases were detected in private sector hospitals, primarily in and around Colombo, the nation's capital. Poor health systems in previous conflict-affected areas in the northern and eastern regions add to the challenge of POR. In addition, there is a decline in the level of interest and awareness among health workers because malaria is no longer considered a major public health threat.[4] To maintain vigilance against malaria, the National Malaria Strategic Plan for Elimination and Prevention of

a The main vector *Anopheles culicifacies* is still present in many parts of the country.

Figure 1. Timeline of reported malaria cases and major events in malaria control and elimination in Sri Lanka, 1911–2014[12]



ACT, artemisinin-based combined therapies; POR, prevention of re-introduction; DDT, dichlorodiphenyltrichloroethane; RBM, Roll Back Malaria

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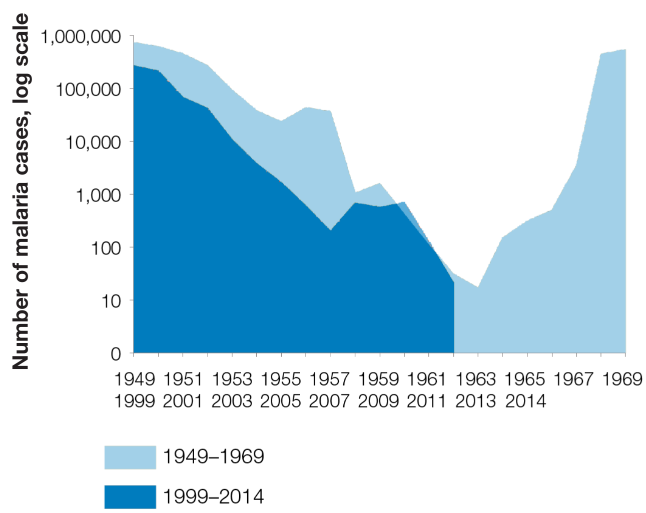
Re-introduction 2014–2018 (NMSP) heavily emphasizes the intensification of surveillance activities and rapid detection and response to emergent cases.[4]

Now that Sri Lanka has succeeded in interrupting local malaria transmission, it faces the challenge of maintaining political and financial support to sustain its gains. Figure 2 illustrates the historical pattern of cases over the past 65 years. Sri Lanka is at a point where the country can remain malaria-free or experience resurgence as it has in the past. To effectively implement its POR strategy, the AMC needs to secure the continued availability of resources, particularly in the short- to medium-term.

Significance of the study

This study was conducted to develop an investment case for malaria POR in Sri Lanka to ensure that sufficient investments are maintained and endemic malaria is not reintroduced. The findings provide the AMC with an estimate of the resources required to prevent reintroduction of malaria to aid budgeting and planning, as well as robust evidence to advocate for sustained financial resources from both domestic and external sources. The study also seeks to inform the development of investment cases for malaria elimination and POR in other countries.

Figure 2. Comparison of the current malaria situation in Sri Lanka with the 1960s[12]



Objectives of the study

The principal objective of this study is to develop an investment case for preventing the reintroduction of malaria in Sri Lanka. Specifically, this study set out to:

- Estimate the current and future costs of malaria POR activities in Sri Lanka;
- Estimate the costs of a potential resurgence of malaria in Sri Lanka;
- Calculate the return on investment (ROI) of malaria POR relative to a potential resurgence; and
- Estimate funding gaps and explore potential sources of financing for malaria POR.

Methodology

This study estimated *the cost of POR* and *cost of resurgence* in Sri Lanka. Under the cost of POR, we calculated the cost of current malaria activities in Sri Lanka and projected it over time. To estimate the cost of resurgence, we generated a counterfactual resurgence scenario based on historical data and calculated the cost of responding to the surge of malaria cases. The cost of resurgence represents the hazards of underinvestment and, if averted, equates to the potential benefits of malaria POR. The two costs were then compared to determine the cost savings from malaria POR and to approximate the ROI of the current malaria program.

Study design

This study used a mixed-methods approach consisting of literature review, data extraction from information systems and malaria program records, micro-costing analysis and cost projection, financial gap analysis, key informant interviews, and direct observation. The time frame used for analysis in this study is six years (2015–2020). All costs were expressed in 2013 U.S. dollar (USD), using a mid-year exchange rate of 131.50 Sri Lankan rupees per USD.

Literature review

We conducted a comprehensive literature review to gain an understanding of the current and historical structure and activities of the malaria program, as well as the financing landscape for malaria in Sri Lanka. Information was extracted from records at the national and regional levels and grey and published literature, including articles from Internet-based searches.

Cost of POR

We conducted micro-costing using an ingredients-based approach to capture economic and financial costs of malaria elimination from the perspective of the public health sector. Data on all direct and indirect costs of delivering current interventions for malaria POR in Sri Lanka were collected. Cost inputs included fixed and recurrent costs incurred by the health system, as well as donations and in-kind contributions. Cost inputs were identified and valued to produce cost estimates. When the most current cost was unavailable, program expenditures from previous years were used as estimates to fill gaps in information. A detailed list of assumptions that were made for the malaria program costing is found in Annex 2.

Cost of resurgence

To estimate the cost of resurgence, we constructed a hypothetical resurgence scenario based on historical data and expert opinion from malariologists, epidemiologists, and entomologists in Sri Lanka and the AMC. Although it is impossible to predict the true probability and magnitude of malaria resurgence, historical experience in Sri Lanka and other countries suggests that the risk is real in the absence of continued efforts to prevent reintroduction (Figure 1).

Though many resurgence scenarios can be used in the analysis, we chose a historical point in Sri Lanka's malaria epidemiology—between 1997 and 2002—to estimate the magnitude of a potential resurgence. The most recent outbreak of malaria in Sri Lanka occurred in 1999, just before the inception of the Global Fund. Under the chosen counterfactual scenario, all POR activities are assumed to have halted in 2014, and that the resulting resurgence in 2015–2020 would mimic the magnitude and trend of the malaria outbreak between 1997–2002. We projected the number of malaria cases for 2015–2020 by adjusting the number of incident cases reported in 1997–2020 by 1.13% population growth rate.

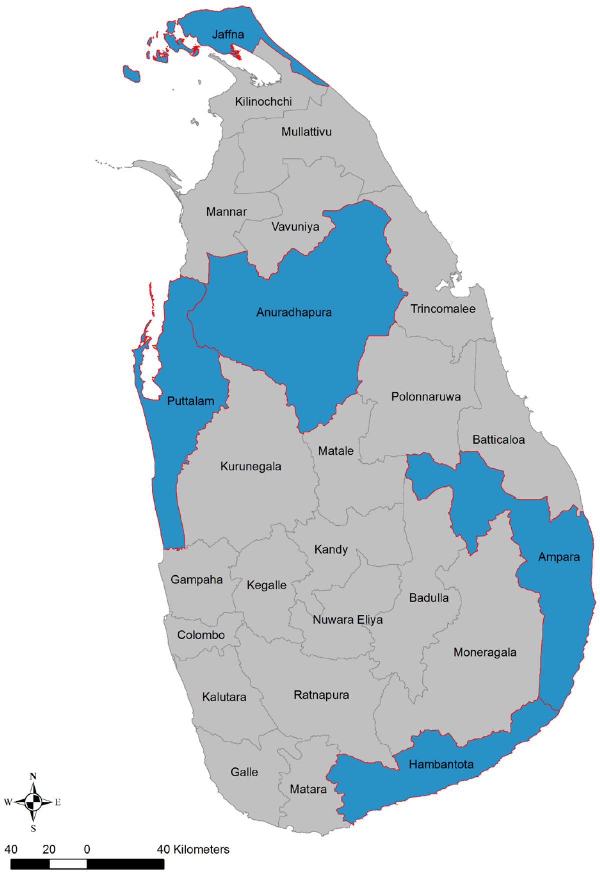
Study setting and sampling

Sri Lanka is divided into nine provinces and 25 administrative districts. Five districts in five different provinces were sampled for data collection on costs (Figure 3): Hambantota (Southern Province), Ampara (Eastern Province), Anuradhapura (North Central Province), Puttalam (North Western Province), and Jaffna (Northern Province). The sampled districts represented regions where recent cases had been identified and included a range of previously endemic regions that employed a mix of POR activities at varying levels. Based on input from the AMC and other in-country experts, these sampled districts were deemed to be representative of the remaining 20 districts with respect to programmatic costs and levels of receptivity and vulnerability to malaria transmission.

Organization of malaria program in Sri Lanka

In Sri Lanka the AMC is the main organizational unit within the MOH that provides technical leadership and strategic management for all malaria control activities in the country. The AMC houses national level experts on malaria prevention, treatment, and epidemiology. At the district level, coordination and implementation of malaria activities are led by Regional Malaria Offices (RMOs) headed typically by regional malaria officers with a team of entomologists, public health inspectors and field officers, spray machine operators, laboratory technicians, and assistants. The AMC serves as the RMO for districts in the Western Province (i.e., Colombo, Gampaha, and Kalutara). Figure 4 (on page 11) illustrates the organizational structure of the AMC.

Figure 3. Five sample districts selected for cost data collection



Data collection

The data collection for this study took place between February and July 2015. Data collectors were trained on each data collection activity and tool used in this study. We organized and analyzed all data in a costing tool developed in Microsoft Excel® 2011. Data were stored on encrypted, password-protected computers.

Costs of POR

We obtained data on the costs associated with malaria POR activities from a combination of interviews, direct observation, and review of financial and expenditure records. Using an interview guide, staff at the AMC and RMOs were interviewed in a semi-structured format and observed to determine how much time they spent on various malaria control activities. At the central level, officers at the AMC including the AMC director; director of finance and accounting; diagnostic, surveillance, and monitoring and evaluation unit staff; and the Global Fund project finance manager were interviewed. At the provincial and regional levels, regional malaria officers and their staff were interviewed and observed at work and during their surveillance outreach events. A complete list of persons interviewed is provided in Annex 1.

Cost of resurgence

We developed a checklist to facilitate data collection on all potential costs of resurgence. Most of the data for the resurgence scenario was collected from existing literature, which we elaborate on below. We also conducted key informant interviews with AMC staff to gather additional data on the cost of resurgence and to build consensus on the assumptions used.

Data analysis

Estimating cost of POR

Data on costs collected from the AMC and each sample district for year 2014 were organized and aggregated according to three predetermined categories: (1) funding source, (2) input, and (3) activity (Table 1). All fixed and recurrent cost data were analyzed based on these categories in order to identify the cost drivers of malaria POR.

Table 1. Categories used to organize cost of POR data

Cost by source	Cost by input	Cost by activity
Domestic (national or provincial) External	Capital Personnel Consumables Services	Prevention and vector control (PVC) Diagnosis (D) Treatment and prophylaxis (TP) Surveillance and epidemic management (SEM) Monitoring and evaluation (ME) Information, education, and communication (IEC) Program management (PM)

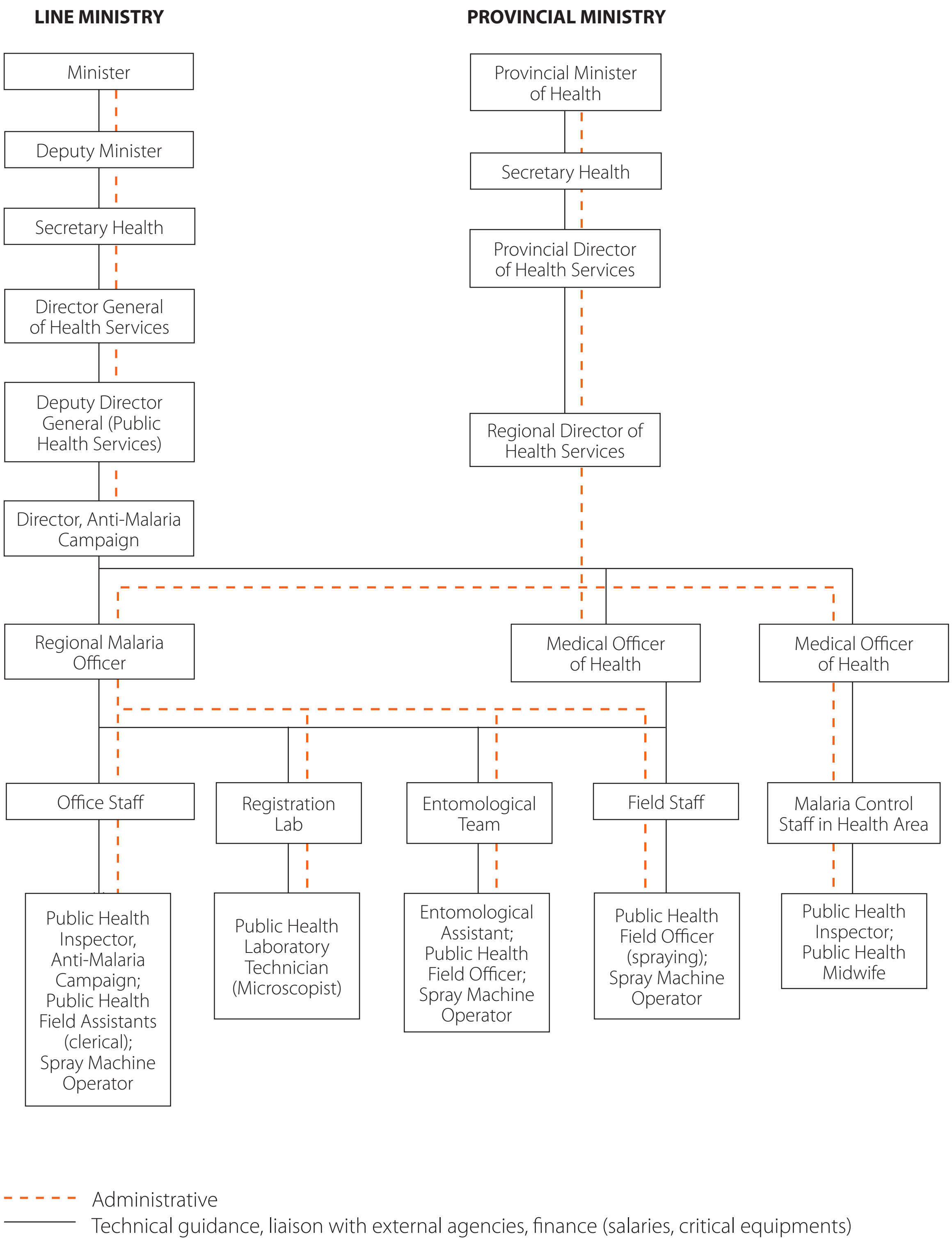
Cost by source

The two main sources of funding for malaria in Sri Lanka are (1) domestic funding, in the form of direct government allocations from the national health budget and (2) external funding, primarily from the Global Fund directly provided to the government. Government resources are disbursed to provinces and districts for all health activities including malaria prevention and control. To the extent possible, we identified the specific source of funding for each input. For inputs shared across multiple health or disease programs, only the cost attributed to malaria was included based on the proportion of time spent on malaria-specific activities. Shared resources such as staff time spent on each activity were self-reported and determined through interviews and likely subject to reporting bias. Due to time and resource constraints, a time and motion study was not conducted.

Cost by input

We classified costs based on four inputs of production: capital, personnel, consumables, and services. Capital costs included vehicles, buildings and office space, furniture, computers, and other durable supplies. Personnel costs included salaries, allowances, and any other compensation to staff involved in malaria. Consumable costs included office and laboratory supplies, medicines, insecticides, and other

Figure 4. Organizational diagram of the Anti-Malaria Campaign[2]



products. Service costs included utilities, transport (domestic and international), training, maintenance, and security. Costs were also categorized as fixed (i.e., capital) and recurrent (i.e., personnel, consumables, and services). Capital goods were annualized and discounted using common useful life years (ULYs) and standard annuity factors based on a 3% discount rate (see Annex 2 for ULYs and annuity factors used). Maintenance costs for equipment, vehicles, and buildings were calculated using actual information on the expenditure of maintaining these resources. No replacement costs were used for the value of capital resources when the current value of such resources was already depreciated to zero, assuming that the replacement would not occur in the near future.[b]

Cost by activity

We classified costs across seven activity groups for malaria: prevention and vector control (PVC); diagnosis (D); treatment and prophylaxis (TP); surveillance and epidemic management (SEM); monitoring and evaluation (ME); information, education, and communication (IEC); and program management (PM). While the conduct of most of these activities is integrated, we created activity groups for this study to facilitate analysis. A detailed list of activities included under each category is provided in Annex 3. Resources were apportioned across activities based on self-reported time spent by interviewees.

National level estimates

To obtain national level estimates of the cost of POR, we first calculated the cost per capita of malaria POR in each of our sample districts by dividing total costs by each jurisdiction's total population. We then matched the 20 non-sampled districts to our five sample districts based on (1) the size of the malaria program and (2) the mix of activities being implemented. We used the total number of staff and the area of each district (measured in square kilometers) as proxies for the size of the malaria program, assuming that larger, more dispersed districts require more resources to conduct surveillance activities. We generated the total cost of malaria POR for 2014 in the non-sampled districts by multiplying their respective population figures[13] by the cost per capita of their matched districts. Costs across all districts were then added with the costs of the AMC to estimate the total cost of POR for the entire country for 2014. We projected the cost of malaria POR in 2015 and beyond by adjusting for economic growth.[14]

Estimating cost of resurgence

We estimated the cost of resurgence as a way to quantify the potential benefits of sustained investments in malaria. Though the returns of investing in malaria extend beyond health and the public health system, it is rarely possible to account for or value all these economic and social benefits.[15] For this study, we estimated the cost of resurgence based on three broad dimensions (Table 2): (1) direct cost to the health system, (2) direct cost to households, and (3) indirect cost to society.

Cost to the health system refers to the direct cost incurred for delivering health services to meet the surge in demand for health care for malaria. Cost to households includes out-of-pocket (OOP) expenditures for products for malaria prevention as well as for seeking care. Cost to society includes the indirect cost borne by society in terms of reduced economic productivity, lost earnings due to ill health, and lives lost due to malaria. The parameters used to estimate the cost of resurgence and their data sources are listed in Table 3.

Direct cost to the health system

Cost of increased health service utilization

We calculated the potential costs to the health system for delivering health care services to all malaria patients under the resurgence scenario separately for uncomplicated malaria (UM) and severe malaria (SM). Unit costs for UM and SM (Table 3) were multiplied by the potential number of cases to estimate the total cost to the health system due to increased utilization of services for malaria.

- **Inpatient care for severe malaria:** Actual costs of inpatient care for malaria were unavailable, as malaria treatment services are integrated within general health services. We thus used the average cost of hospital admission for all patients (regardless of original complaint or final diagnosis) derived from a micro-costing database from a teaching hospital in Kurunegala as the cost of inpatient (IP) care for malaria.[1] This average admission cost is the product of the length of hospital stay and the average cost of a hospital bed per day in 2014. In Sri Lanka, it is recommended to admit a confirmed malaria patient for three days in a health facility.[17] However, in practice, providers admit severe cases for four days, which was the duration used in the IP cost calculations. The cost of an average course of antimalarials (reported by the AMC) was also added to approximate the total cost of a malaria IP admission.
- **Outpatient care for uncomplicated malaria**: Similar to the cost of inpatient care, the cost estimate per outpatient (OP) visit was derived from a 2014 micro-costing database from the same teaching hospital in Kurunegala.[16] The average OP visit cost includes the cost of OP consultation and diagnostic tests and the cost of an average course of antimalarials.

In all cases the supply chain costs for antimalarials were estimated to be 25% of the acquisition cost of the product.[18] This amount was added to the unit cost.

Cost of vector control

The cost of two major vector control interventions, namely IRS and distribution of long-lasting insecticidal nets (LLINs), were used to measure the cost of vector control under the resurgence scenario. We estimated the cost of reaching specific coverage targets for LLIN distribution and IRS. We assumed that under the resurgence scenario, the country would resume IRS in 4% of the total population, similar to the IRS coverage rate in 1999.[19] In addition, we assumed an LLIN coverage of 1 net per 1.8 people, based on WHO recommendations[21], in the provinces at risk that were identified in collaboration with the AMC based on the current receptivity and vulnerability to malaria. Costs for procurement, distribution, and delivery of LLINs and IRS were obtained from WHO Global Malaria Programme[27] and were added to the cost of vector control.

b The no likelihood of replacement was based on the discussion with the AMC.

Table 2. Categories used to organize the cost of resurgence

Direct cost to the health system	Direct cost to households	Indirect cost to the society
Cost of increased health service utilization for malaria (inpatient and outpatient treatment)	Out of pocket expenditure incurred due to malaria	Cost of lives lost due to malaria
Cost of vector control to control a resurgence		Cost of lost productivity due to malaria morbidity
Cost of treatment for population with special needs (malaria in pregnancy)		
Cost of increased diagnosis of fever cases		
Cost of training human resources and educating the community		

Cost of treatment for population with special needs

We considered pregnant women as a population with special needs. Pregnant women have a higher risk of contracting malaria that may result in maternal anemia, low birth weight, preterm delivery, and increased infant and maternal mortality. In endemic countries, the median proportion of women with peripheral infection has been estimated at 15.3% and that of placental malaria at 11%.[28] In areas of low, unstable malaria transmission, such as the Asia-Pacific region, pregnant women have a lower level of acquired immunity and malaria infections are more likely to develop into clinical disease.[25] Studies also show that despite relatively low transmission rates, subclinical malaria infections also occur frequently, necessitating the use of chemoprophylaxis to prevent malaria in pregnancy.[28]

In Sri Lanka, pregnant women are routinely screened and treated for malaria at antenatal clinics. Nevertheless, the presence of placental malaria will place an additional burden on the health system. An increase in malaria incidence will necessitate the resumption of intermittent preventive treatment in pregnancy (IPTp) using sulphadoxine pyrimethamine (SP) at least twice during the pregnancy. We estimated the number of pregnant women who would receive SP during antenatal care visits and multiplied that by USD 1.50, which is the cost per person protected by SP obtained from the Malaria in Pregnancy Consortium.[24]

Cost of increased diagnosis of fever cases

Under the resurgence scenario, it is likely that the program would broaden the list of symptoms that would require a malaria test, leading to excess spending on diagnostic tests (both rapid diagnostic tests [RDTs] and microscopy) in an effort to diagnose and treat all malaria cases. We therefore estimated the cost of diagnosing fever cases for malaria. Based on slide positivity rates from 1999, we assumed that 16.7% of cases tested for malaria would be positive with the remaining 83.3% cases tested being parasite negative.[19] The cost of increased diagnosis of non-malarial fevers was thus derived by multiplying the number of potential non-malarial fevers (i.e., negatives tested) by the average cost of malaria testing (i.e., cost of RDTs and microscopy slides plus the cost of administering a test).[27]

Cost of training human resources and educating the community

In case of malaria resurgence, the AMC would likely conduct refresher trainings for providers on malaria diagnosis and treatment, as well as additional IEC activities for the public. In this study, we assumed the costs of IEC and training during resurgence to be twice their estimated costs in 2014, which were obtained through our micro-costing work.

Direct cost to households[c]

OOP expenditure incurred due to malaria

OOP expenditures due to malaria include both direct and indirect costs incurred by households in preventing or seeking care for malaria. These include expenses of patients and caregivers when accessing health facilities (e.g., transport costs), as well as spending on products meant to prevent malaria (e.g., bed nets, mosquito coils, and repellents). While these items are not costly, they tend to be consumed on a regular basis, thereby potentially impacting a family's budget. Data on household OOP expenditures were taken from a study done in Sri Lanka in 1994[22] and were adjusted to current prices.

Indirect cost to society

Cost of lives lost due to malaria

Following the proposal of the Lancet Commission on Investing in Health, we used the full income approach (Figure 5) to estimate the potential social value of life lost due to malaria.[29] The full income approach combines growth in national income with the value individuals place on increased life expectancy, or the value of their additional life years (VLYs). This approach accounts for people's willingness to trade off income, pleasure, or convenience for an increase in life expectancy. One VLY is the value in a particular country or region of a 1-year increase in life expectancy.

Figure 5. Full income approach[33]

To estimate the cost of life lost due to malaria mortality using the full income method, we multiplied the potential number of adult deaths due to malaria by the remaining life years at death and the VLYs. The number of deaths among adults (i.e., persons age 15 years and above) in the hypothetical resurgence were projected based on deaths during years 1997 and 2002. The average life expectancy at age 40 years

c Other cost incurred by the household such as income foregone from lost working days due to malaria is measured as the indirect cost to society.

Table 3. Input parameters and the data sources

Parameters	Values	Reference
Population and economy		
Population	Year 1999: 18,754,185 Year 2015: 20,964,378*	13
GDP per capita	Year 1999: USD 2,135.70 Year 2015: USD 3,839.00	20
GDP growth rate	Year 2015: 7.4% Year 2015: 317,156*	20
Malaria epidemiology		
Number of cases	Year 1997–2002: 1,012,762 Year 2015-2020: 1,241,775*	19
Distribution of cases by gender	Year 1999: Male 54%, Female 46% Year 2015: Male 90%, Female 10%**	19
Distribution of cases by age	Year 1999: <15 years 41%, >15 years 59% Year 2015: <15 years 6%, >15 years 94%**	19
Number of deaths	Year 1999: 102 Year 2015: 122.3***	19
Proportion of uncomplicated cases	75%	19
Proportion of severe cases	25%	19
Proportion of *P. vivax* cases	76%	19
Proportion of *P. falciparum* cases	24%	19
Slide positivity rate	16.72%	19
Total blood films tested	1,582,111	19
Proportion of population protected by IRS	4% twice a year	19
Number of LLINs needed	1 LLIN per 1.8 population	21
Cost		
Number of days lost due to a malaria illness	9.3 days	22
Cost of OP treatment	USD 1.68	16
Cost of IP admission	USD 24.49	16
Cost of malaria medicines (OP)	USD 1.00	19
Cost of malaria medicines (IP)	USD 8.50	19
Cost of IRS per person protected	USD 4.37	23
Cost of LLIN distributed	USD 6.87	23
Cost of testing non-malaria fevers	USD 1.12 per RDT USD 0.86 per microscopy slide	23
Cost of administering SP during pregnancy	USD 1.50	24
Cost of household consumption goods for malaria	USD 7.31	22
Malaria in pregnancy		
Number of pregnant women	Year 2015: 340,664	19
Number SP tablets administered by directly observed therapy	9	19
Proportion of pregnant women infected with malaria	15%	25
Tourism		
Annual number of tourists in Sri Lanka	Year 1999: 436,440 Year 2015: 1,889,211	26
Average nights spent by tourists	Year 1999: 8.6 Year 2015: 9.25***	26
Average revenue per tourist per day	USD 158.65	26
Proportion of tourists from Europe and North America	67%	26

*Projected for 2015 by authors based on population growth rates from UN
**Distribution for year 2015 based on 2011 data
***Projected for 2015 by authors

was used as a proxy for the remaining life years at death due to malaria (calculated separately for male and female). The Commission on Investing in Health estimates the VLY average across low- and middle-income countries to be 2.3 times the income per capita at a 3% discount rate.[29] Data on Sri Lanka's gross domestic product (GDP) per capita for 2013 was obtained from the World Bank.[20]

Cost of lost productivity due to malaria morbidity

The lost earnings from an episode of illness due to malaria can have a significant impact on society. We estimated the loss in income and productivity due to malaria morbidity among the adult population by multiplying the potential malaria cases among this age group by the average days lost to one malaria episode[22] and the average income (GDP) per capita per day.[20]

Other distal societal costs of resurgence

The costs of resurgence extend beyond health, and these indirect costs likely account for the largest share of the societal burden of malaria. For example, frequent illness episodes due to malaria and associated school absenteeism have been shown to affect children's educational performance.[30–32] In addition to its debilitating physical impacts, malaria could affect the cognitive abilities of children imparting further negative consequences on educational performance.[33,34] Lucas (2010) estimated that ending malaria in the most heavily affected region in Sri Lanka led to an estimated 17% increase in literacy.[35] While there is an obvious negative correlation between malaria and cognitive development, it is unclear how to value poor educational performance empirically and in economic terms. Quantifying this effect requires several assumptions about poor educational performance in childhood and the subsequent loss of earnings.

The effect of malaria on tourism has also been reported in the literature and can reduce the number of tourist arrivals, especially from non-endemic countries.[36,37] In Sri Lanka, roughly two-thirds of tourists are from Europe and North America who, on average, stay 10 days in the country and spend USD 160 per capita per day.[26] Decline in even a small fraction of tourists from these non-endemic areas would lead to an enormous loss to Sri Lanka's economy. In addition to these effects, resurgence of malaria is likely to induce many other macroeconomic consequences, for example via changes in demographic composition.

Though such societal costs are very difficult to quantify, in this study we attempt to estimate the cost of malaria on tourism and educational attainment. However, these costs are not included in our calculation of the ROI.

Return on investment

The ROI on malaria was calculated by taking the difference between the cost of POR and the cost of resurgence, and dividing the resulting number by the cost of POR.

We recognize that the methods used in estimating the cost of POR and the cost of resurgence are slightly different. The former uses a public sector perspective whereas the latter considers a slightly broader perspective to include many societal level benefits, though not all. Furthermore, cost of POR is computed from an input perspective using an ingredients-based micro-costing, whereas the cost of resurgence is computed from an output perspective where costs are multiplied by quantities estimated under a resurgence scenario.

To ensure that the cost of POR and cost of resurgence were comparable and used similar perspectives, we calculated two sets of ROIs, one that included only health system costs and the other including the broader costs of resurgence.

Uncertainty analysis

Estimates of both cost of POR and cost of resurgence are built on numerous underlying assumptions. These assumptions are necessary in order to draw conclusions from available evidence. We conducted sensitivity analysis to estimate the uncertainty of the cost estimates by varying a set of assumptions (Table 4). To test the sensitivity of cost of POR, we varied the discount rate used in valuing capital expenditure between 1 and 7%. For the cost of resurgence, we varied key input parameters. First, we adjusted the magnitude of the resurgence scenario to generate various ROI estimates. Scenario 1 applies a 25% increase in malaria cases from the median estimate (referred to as Scenario 2), which is based on the number of reported malaria cases in 1997-2002 after adjusting for population growth. Scenarios 3 and 4, on the other hand, respectively apply 25% and 50% decreases in the projected malaria burden from Scenario 2. Second, using data from two time periods (i.e., 1999 and 2011), we changed the distribution of cases by age and gender. In 1999, the year when the last epidemic of malaria was observed, malaria cases were more evenly split across age groups and sexes. In 2011, the year when last indigenous malaria cases were observed, malaria cases were mostly among adult males (>90% cases).

Table 4. Parameters for sensitivity analysis

Assumptions	Parameters affected	Remarks
Discount rates varied between 1% and 7%	Capital expenditures used to estimate cost of POR	Baseline estimate: uses 3% discount rate
Number of malaria cases increase by 25% and decrease by 25 and 50%	All parameters for estimating cost of resurgence	**Scenario 1**: median estimate increased by 25% **Scenario 2**: median estimate of malaria cases **Scenario 3**: median estimate decreased by 25% **Scenario 4**: median estimate decreased by 50%
Distribution of malaria cases by age and gender varied based on 1999 and 2011 epidemiology	Age- and gender-specific parameters	**Year 1999**: malaria cases evenly split across age groups and sexes **Year 2011**: >90% of malaria cases among adult males

Gap analysis and opportunities for resource mobilization

We collected data on malaria funding in Sri Lanka from various sources. From this data we were able to calculate the financial gap by subtracting the projected cost of POR activities from the projected funding available for malaria. Lastly, we assessed potential opportunities for resource mobilization by mapping the main private sector investors and analyzing the domestic funding landscape.

Results

Cost of POR

The total cost of the malaria program in 2014 was estimated to be USD 11.74 million. Fifty eight percent of the total cost was incurred by the AMC while the remaining 42% was incurred at the peripheral level.[d] Cost estimates varied widely across the districts from less than USD 30,000 to about USD 500,000 per year. The median cost was USD 195,316 for the district level, with a cost per capita ranging from USD 0.21 to 0.54. Overall, the estimated national level cost per capita was USD 0.50 for 2014. After adjusting for economic growth, the projected cost estimates for 2015 are shown in Table 5.

Table 5. Estimated cost of malaria activities for year 2015

District	Total cost (USD)	Cost per capita
Ampara	161,163	0.24
Anuradhapura	270,870	0.30
Badulla	289,154	0.34
Batticaloa	164,117	0.30
Galle	412,625	0.38
Hambantota	338,462	0.54
Jaffna	205,352	0.34
Kandy	485,502	0.34
Kegalle	206,589	0.24
Kilinochchi	28,512	0.24
Kurunegala	504,622	0.30
Mannar	39,279	0.38
Matale	189,151	0.38
Matara	287,769	0.34
Monaragala	177,711	0.38
Mullaitivu	32,552	0.34
Nuwara-eliya	279,532	0.38
Polonnaruwa	100,274	0.24
Puttalam	168,417	0.21
Ratnapura	386,116	0.34
Trincomalee	149,109	0.38
Vavuniya	61,294	0.34
AMC*	6,920,844	0.33
Total	11,859,017	0.57

*AMC costs include cost of the malaria program in the Western Province.

d The AMC serves as the RMO for three districts in the Western Province (namely Colombo, Gampaha, and Kalutara) and the cost of malaria POR in those districts are also included into AMC cost. We were unable to separate the cost of program for these districts from the AMC costs we collected.

Cost by source

In Sri Lanka, about 76% of the total expenditure for malaria was funded by domestic sources, of which 30% was from provinces and 70% was from the national government. The remaining 24% of the funding for malaria was from the Global Fund. Funding for the AMC was primarily domestic (82%) and the remaining 18% from the Global Fund. Across the sample districts, sources of funding varied largely with an average of 71% domestic (of which 13% was national and 58% was provincial) and 29% donor.

Cost by inputs

The distribution of cost across inputs is shown in Figure 6. Human resources constituted the largest share (about 83% of the total cost) followed by capital resources at about 13%. Consumables and services together constituted about 5% of total expenditure on malaria.

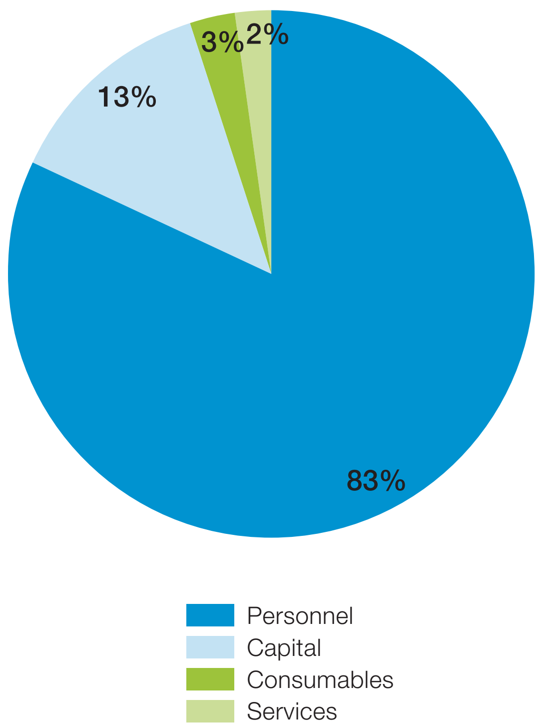
Input costs were not evenly distributed across the districts or the AMC (Table 6 and Figure 7). However, human resources constituted the majority of the cost across all sample districts, ranging from 62% to 90%. This is not unusual for malaria elimination programs, which are by nature service-heavy rather than commodity-heavy. The share of capital cost was on average 22% (range 9–30%). Consumables constituted on average <1% of the total cost (range <1–3%), and services constituted on average about 3% of the total cost (range <1–5%).

Cost by activity

Figure 8 illustrates the distribution of total costs across activities in the country. Overall the major cost drivers at all levels were PM and SEM, followed by PVC and D. In general, PM comprised the largest share of the total cost, at about 63%, followed by SEM at about 12%, and PVC activities at 9%.

The cost share of different POR activities also varied widely across sample districts, as shown by Figure 9. At the district level, SEM constituted the major fraction of cost at an average of 33% (range 21–44%). Across the districts, the cost share for PVC averaged around 19% (range 11–28%). Similarly, the cost share of D ranged between 8 and 24% with an average of 16%. The cost share of IEC was fairly stable across districts with an average of around 5% of the total cost.

Figure 6. Distribution of total cost by inputs*



*Proportions may not add up to 100 due to rounding off.

Figure 7. Distribution of input cost across sample districts

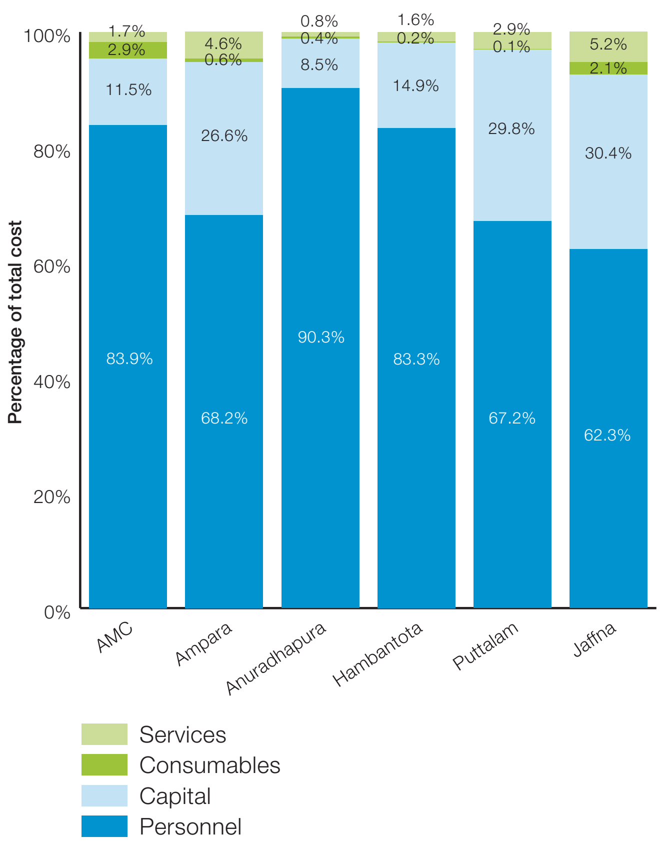


Figure 8. Distribution of total cost across activities

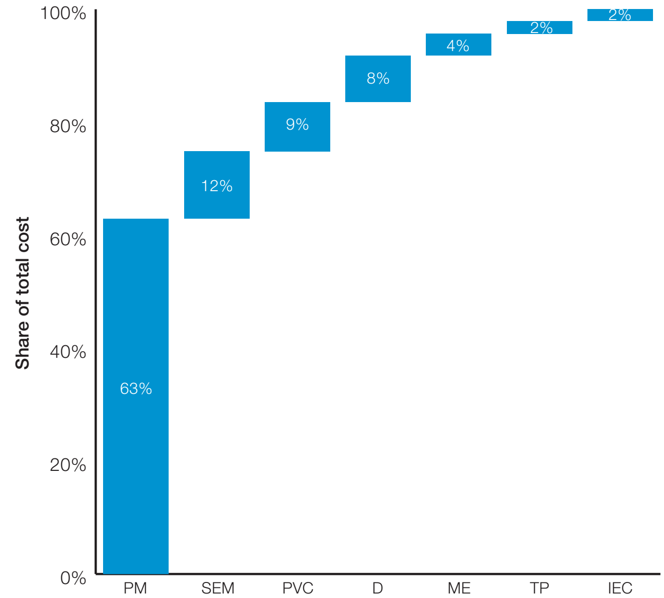


Figure 9. Distribution of cost by activity across districts

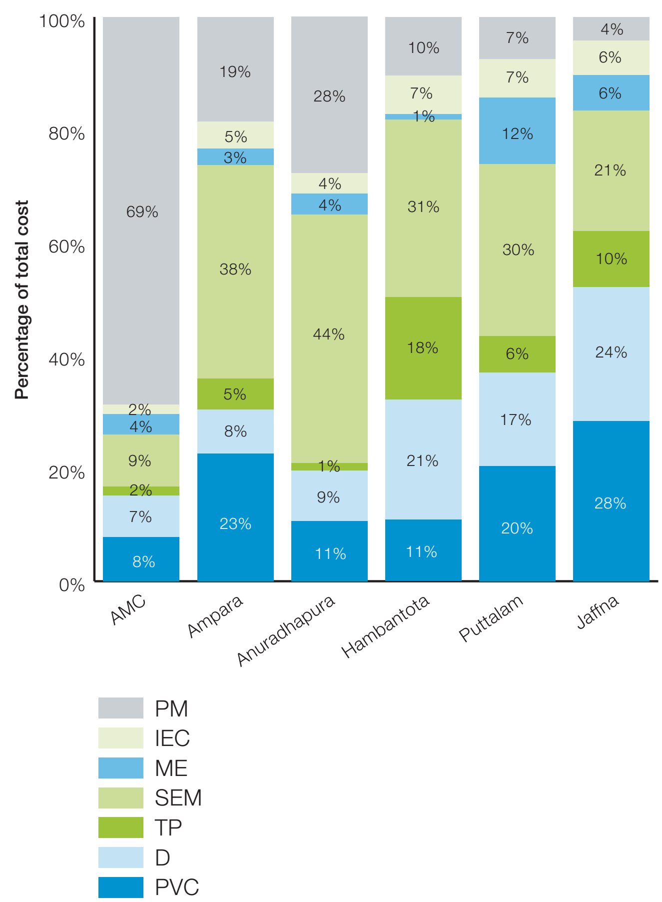


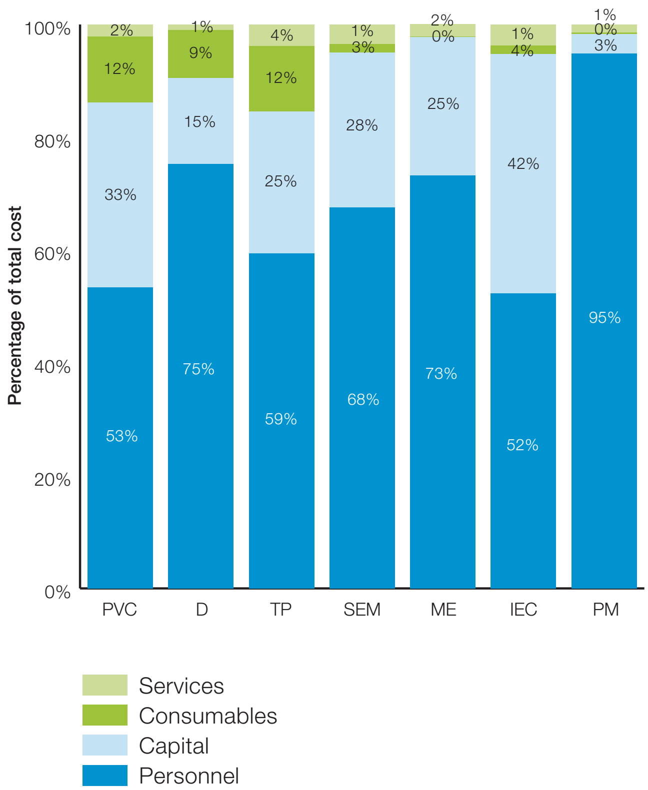
Table 6. Distribution of input costs across sample districts and the AMC in 2014

Region	Capital		Personnel		Consumables		Services	
	Cost (USD)	%	Cost (USD)	%	Cost (USD)	%	Cost (USD)	%
AMC	788,821	12	5,746,632	84	201,581	3	115,906	2
Ampara	42,469	27	108,861	68	892	<1	7,361	5
Anuradhapura	22,907	9	242,277	90	991	<1	2,037	<1
Hambantota	49,917	15	279,217	84	595	<1	5,412	2
Puttalam	49,623	30	112,113	67	181	<1	4,847	3
Jaffna	61,738	30	126,679	62	4,299	2	10,620	5

Distribution of input cost across activities

Across all activities, human resources constituted the highest share of cost, followed by capital. The most human resource-intensive interventions were PM, SEM, and ME. IEC was the most capital-intensive intervention. As expected, TP, followed by PVC and D constituted relatively higher shares of consumable cost than other activities. Variations in the share of inputs across activities are depicted in Figure 10.

Figure 10. Distribution of input cost across activities



Cost of future activities to prevent reintroduction

The recently adopted NMSP 2014–2018 prioritizes strengthening of existing interventions for malaria, particularly surveillance and response for the early detection of cases and their effective treatment, maintaining skills for diagnosis and treatment, strengthening preparedness for epidemic and outbreak response, and entomological surveillance through integrated vector management (Annex 4).[4] It is anticipated that the cost of continuing POR over the next 3–5 years will be similar to the cost of the program in 2014.[e] We thus projected the cost for 2015–2020 using the estimates from 2014, assuming a steady economic growth rate of 6.4%.[20] The estimated cost to sustain the current level of activities for malaria between 2015 and 2020 is approximately USD 83.6 million or USD 14.0 million per year on average (Table 7).

The NMSP 2014–2018 estimated that an annual budget of USD 10 million per year between 2015 and 2018 is required for the implementation of malaria elimination and POR activities in Sri Lanka.[4] The difference between our estimates and the NMSP budget is largely due to our estimates being based on current strategies (instead of proposed activities) and the inclusion of existing human resource and the capital costs that the NMSP budget did not consider.

Table 7. Projected cost of malaria POR, 2015–2020

Year	Estimated cost (USD)	Cumulative cost (USD)
2015	11,859,017	11,859,017
2016	12,617,994	24,477,010
2017	13,425,545	37,902,556
2018	14,284,780	52,187,336
2019	15,199,006	67,386,342
2020	16,171,742	83,558,084

e This assumption was made in consultation with the AMC.

Table 8. Actual and projected expenditures for the malaria program in Sri Lanka 2012–2017

Source of Funding	Actual funds spent (USD)			Projected funds (USD)		
	2012	2013	2014	2015	2016	2017
Domestic spending*	3,266,175	3,629,955	5,060,546	5,487,360	6,116,064	6,765,291
Global Fund support**	2,906,586	3,129,799	3,724,106	2,466,667	2,466,667	2,466,667
Total budget for malaria	6,172,761	6,759,754	8,784,652	7,954,027	8,582,731	9,231,958
Total domestic spending on health	758,116,585	841,509,409	934,075,444	1,036,823,743	1,150,874,355	1,277,470,534
% of domestic funding for malaria	53	54	58	69	71	73
% of domestic health budget allocated for malaria	0.43	0.43	0.54	0.53	0.53	0.53
Malaria budget as a % of total domestic health spending	0.81	0.80	0.94	0.77	0.75	0.72

*Based on data published by the Central Bank of Sri Lanka (www.cbsl.gov.lk)

**During the time of this study, Global Fund support amounting to USD 9.6 million was requested for 2014–2017, and we used this amount in our financial and gap analysis. (After subtracting the 2014 disbursement of USD 3.7 million from the total, we divided the remaining amount across 2015–2017). In early 2016, however, a new Global Fund grant of USD 7.0 million for 2016–2018 was approved for Sri Lanka, reducing the projected Global Fund support in 2016 and 2017 by approximately USD 116,000 per year on average.

Financing of malaria POR in Sri Lanka

Table 8 provides the actual and the projected expenditures on malaria from 2012–2017. The domestic funding for malaria reported in the table includes direct funding from the national government to the AMC for malaria-specific activities only. The cost of technical assistance on malaria from the WHO and other organizations was not available and is not included here.

Malaria activities in Sri Lanka are financed primarily through domestic sources, representing 58% of total funding (or USD 8.8 million) in 2014 (Table 8). This figure is only about 1% of total government spending on health in Sri Lanka, which was estimated to be USD 934.1 million in 2014.

Sri Lanka's malaria control program has benefitted from external financing from various institutions such as the Global Fund, U.S. Agency for International Development, WHO, and UNICEF. As with most eliminating countries, the Global Fund has been the main external financier for malaria control and elimination in Sri Lanka in recent years. In 2003, Sri Lanka received its first Global Fund grant for USD 7.3 million, followed by USD 3.7 million during Round 4.[38] Although Sri Lanka had already reached the WHO-defined elimination phase in 2004 (<1 case per 1000 population at risk), the country launched its pre-elimination program in 2008, re-orienting its activities toward elimination. In 2009, Sri Lanka was granted an additional USD 21.6 million from the Global Fund to support a phased strategy to eliminate *P. falciparum* and reduce *P. vivax* by 75%.[38] In 2014, the Global Fund's contribution was USD 3.7 million; 42% of the total funding for malaria.[4] This funding was used for scaling up IRS, active surveillance through mobile clinics, diagnosis and treatment, and LLIN distribution.

Gaps in financing malaria POR

We calculated the financial gap for malaria POR in Sri Lanka by comparing estimated costs (Table 7) with projected financing (Table 8). Assuming that the planned budget from the Global Fund gets approved for 2015–2017,[f] our estimates suggest that Sri Lanka faces a significant gap of around USD 12.1 million (in total) for malaria, or an average of USD 4.0 million per year in the same time period (Table 9). If donor financing for malaria in Sri Lanka were to stop immediately, this would leave a gap of USD 19.5 million between 2015 and 2017, or approximately USD 6.5 million annually.

Table 9. Gaps in financing malaria (in USD)

	2015	2016	2017
Total need	11,859,017	12,617,994	13,425,545
Domestic resources	5,487,360	6,116,064	6,765,291
External resources (expected Global Fund support)	2,466,667	2,466,667	2,466,667
Financial gap	3,904,990	4,035,263	4,193,588

As previously discussed, current financing for malaria in Sri Lanka is primarily domestic. Of the domestic resources, 30% is from provincial budgets and 70% is from the national government. The national budget and donor support for malaria are more likely to be volatile sources of funding especially in the context of reduced burden. While provincial funding is

f During the time of this study, the AMC requested USD 9.6 million from the Global Fund for 2014-2017, and this was the amount we used in our financial and gap analysis. However, in early 2016, the Global Fund approved a grant of USD 7.0 million for 2016-2018 after a delay in negotiations.

likely to remain a stable source for malaria activities, our estimates show that this only accounts for approximately 20% of the total need, leaving a gap of about 80%.

Cost of resurgence

We estimated the median cost of a potential resurgence in 2015 to be USD 169.5 million, based on the distribution of malaria cases by age and gender in 2011. Within this cost of resurgence, the direct cost to the health system was USD 121.8 million, the cost to households was USD 2.0 million, and the cost to society was about USD 45.7 million (Table 10).

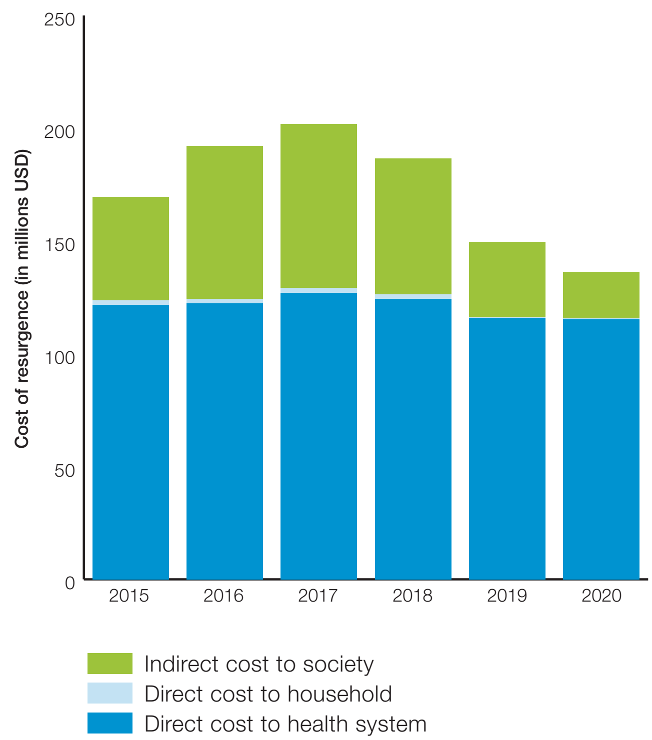
As the number of malaria cases peak in our resurgence scenario, the cost of resurgence increases. The cost is projected to be highest in 2017 at the peak of incident cases, and then descend following case trajectory. Figure 11 illustrates the cost of resurgence between 2015 and 2020. The majority of the cost is incurred by the health system followed by cost to society.

In addition to the costs of resurgence incurred by the health system, households, and larger society (Table 10 and Figure 11), we explored other distal macroeconomic costs of malaria that we excluded from the cost-benefit analysis or ROI calculation. Assuming that malaria resurgence would reduce tourist arrivals by 50% from non-endemic countries in Europe and North America (Table 3), we estimate that Sri Lanka may incur losses from the tourism industry as high as USD 932 million in 2015 alone. In addition, the resurgence could potentially lead to long-lasting impact on cognitive ability of children thereby reducing their economic productivity and income as adults. This loss of future earnings was estimated to be USD 161 million.

Table 10. Cost of resurgence of malaria in 2015

Source of cost	Estimated cost (USD)
Direct cost to the health system	
Cost of increased health service utilization	14,632,248
Cost of vector control to control resurgence	104,077,760
Cost of treatment for people with special needs	510,996
Cost of increased diagnosis	1,304,406
Cost of training human resources and educating community	1,310,045
Direct cost to the individual household	
Out-of-pocket expenditure due to malaria	1,958,863
Indirect cost to the society	
Cost of lives lost due to malaria	21,126,276
Cost of lost productivity due to malaria morbidity	24,540,296
Total cost of resurgence	169,460,890

Figure 11. Cost of resurgence of malaria in Sri Lanka



Return on investment

The total cost of malaria POR in Sri Lanka for 2015 is estimated to be USD 11.9 million and the total cost of resurgence for the corresponding year is estimated to be USD 169.5 million, yielding an ROI of 13.3 to 1. When considering the cost of resurgence on the health system alone, the ROI of investing in malaria POR is 9.3 to 1.

Uncertainty analysis

We conducted uncertainty analyses using various levels of discount rates (1–7%) in costing capital resources. For 2015, the difference in cost between the different discount rates was less than USD 0.2 million (data not shown).

The estimates of ROI under different scenarios are illustrated in Figures 12 and 13. Figure 12 includes the ROI estimates under the assumption that the cases follow the age and sex distribution pattern in year 2011, while Figure 13 assumes the cases follow the pattern in year 1999. In our view, case distribution in year 2011 would reflect a more realistic case distribution if the resurgence were to occur.

Under the 2011 case distribution assumption (Figure 12), the median estimate of the cost of resurgence (Scenario 2) was USD 169.5 million with a range of USD 138.3 million (Scenario 4) and USD 185.0 million (Scenario 1). The ROI of investing in POR for year 2015 thus varied between 10.7 and 14.6 for Scenarios 4 and 1 respectively. The cost of resurgence starts declining as the resurgence is contained after the peak year in 2017, leading to a reduction in ROI thereafter.

Figure 12. Sensitivity analysis on ROI using case distribution in 2011

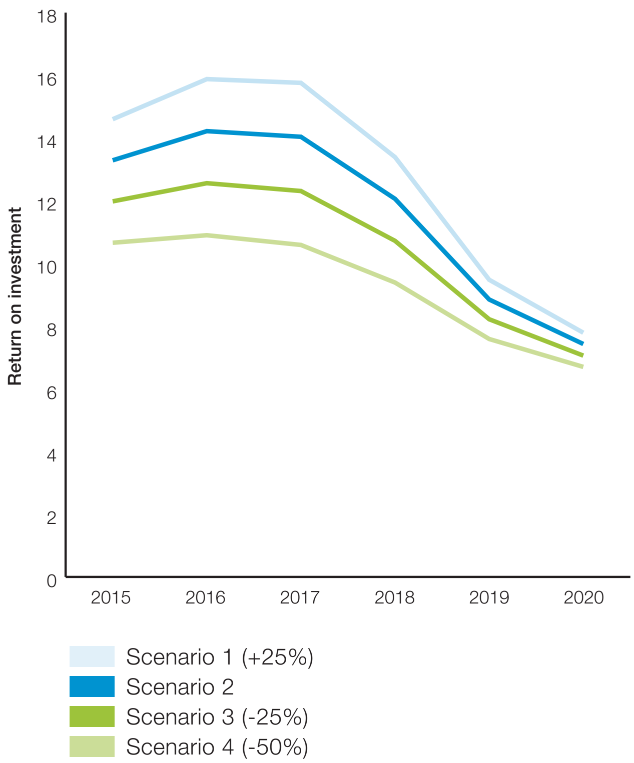
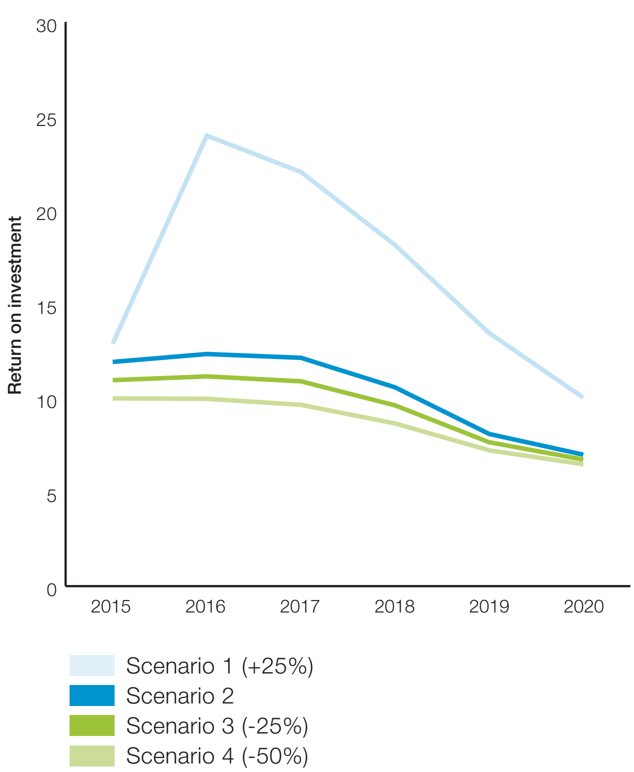


Figure 13. Sensitivity analysis on ROI using case distribution in 1999



Similarly, assuming the case distribution of 1999 (Figure 13), the median estimate of the cost of resurgence (Scenario 2) was USD 153.3 million with a range of USD 130.2 million (Scenario 4) and USD 164.8 million (Scenario 1). Under this assumption, the ROI of investing in POR for year 2015 was 11.9 with a range between 10.0 and 12.9 for Scenarios 4 and 1 respectively.

Opportunities for resource mobilization

Achieving the goals of malaria elimination requires both political and financial commitment from the government, donor agencies, and other stakeholders. Our analysis suggests a funding gap of about USD 4.0 million per year for malaria in Sri Lanka between 2015 and 2017.

Domestic financing for malaria in Sri Lanka for 2014 was USD 5.1 million.[39] which meets only about 46% of the total need for the malaria program in the country. In order to fill the financing gap in year 2015, which is estimated to be about USD 3.9 million, domestic financing will need to increase by about 70%. Uncertainty around Global Fund support to Sri Lanka due to recent changes in the Global Fund's allocation model increases the likelihood that this funding gap will grow further.

Sri Lanka currently allocates only about 0.53% of its total domestic health spending on malaria POR. A recent analysis by Jha and colleagues[40] suggests that if Asian countries were to allocate 2% of their health budgets to malaria, the funding gap would be reduced significantly. Identifying new sources and methods of funding, especially domestic sources, is imperative to maintaining the gains in malaria elimination in Sri Lanka.

Sri Lanka's economy has experienced strong growth rates in recent years. The country's economy grew by 7.4% during 2014, up from 7.2% a year earlier.[41] In 2013, the service sector contributed more than 57% to GDP, followed by the industrial sector (32.4%), and agriculture (10.6%).[14] Sri Lanka's flourishing economy presents an opportunity for the government to increase its domestic allocations for health and funding for malaria.

One mechanism for increasing government revenue is through taxes. Sri Lanka's national tax revenues amounted to about USD 8.3 million in 2013, constituting 13.1% of the total GDP of the country in 2013.[41] The Addis Ababa accord for the Sustainable Development Goals recommends that countries with government revenue below 20% of GDP from taxes should progressively increase tax revenues to meet the 20% target by 2025.[42] Raising tax revenues to reach 20% of GDP would generate additional revenue of around USD 4.4 million in Sri Lanka annually, providing the government a clear opportunity to invest in disease control and sustainable systems to prevent malaria reintroduction.

Other potential sources of funding for malaria elimination in Sri Lanka are large multinational firms that have corporate social responsibility (CSR) programs. These companies currently play an important role in Sri Lanka's economy.[g] Ceylon Tobacco Company contributed USD 556 million to government revenue in taxes, excise, and levies in 2013.[43] Another private conglomerate, John Keells Holdings, operating 85 companies in major industry sectors across the country, accounts for more than 14% of Sri Lanka's stock market, and it contributed USD 18.3 million in tax revenue in 2014.[44] A total of 40 companies collectively spend about USD 30.5 million annually on CSR covering a wide range of development issues, though it is unclear how much of this total is spent on philanthropy alone.[43] Some of the areas covered by existing CSR funds are environmental protection, awareness and prevention of health risks, capacity building, and youth empowerment. Specifically, the Ceylon Tobacco Company has invested in a Sustainable Agricultural Development Program, adding about 30–47% to the monthly income of poor households that benefitted from the program. Similarly, the John Keells Foundation aligned its focus with the attainment of the Millennium Development Goals. The CSR consortia has also partnered with Sri Lanka's Public Health Department for dengue eradication. None of the companies (or the CSR consortia) has yet specifically invested in the malaria elimination agenda. Getting the private sector companies interested in malaria elimination would possibly allow the country to tap CSR resources.

Another prominent mechanism for raising additional resources for health is by fiscal policy interventions. Removing or reducing the level of subsidies provided by the government to certain industries would help the government free up resources for health. For example, the government in Sri Lanka provides significant subsidies on fossil fuels. Removing these would generate an additional income that can be used for health programs including malaria. Additional revenues for health can in part be achieved by raising taxes on harmful products such as alcohol and tobacco, referred to as "sin taxes", which have been successfully implemented in other Asian countries. For example, the Philippines has instituted a "sin tax" that generated an additional USD 2.3 billion in revenue during the first two years of implementation.[45] As a result, funding for health in the Philippines increased by 57.3% in 2014 and 63.2% in 2015 over 2013 levels. An Asian Development Bank report on tobacco taxes suggested that a 50% increase in price arising from roughly a 200% tax increase would yield about USD 24 billion more in revenue in China, India, the Philippines, Thailand, and Viet Nam alone.[46]

The Sri Lankan government has already adopted a policy for discouraging the consumption of alcohol and smoking by raising taxes on both products in recent years. Taxes on tobacco were 73.5% of the average retail prices in 2014.[47] Similarly, the excise tax rates on alcoholic beverages were up to 40% of the retail price in 2012.[48] In 2015 alone, taxes on alcohol rose by 48.9%. Taxes on alcohol and tobacco products are a significant portion of the government revenue in Sri Lanka. In 2013, the total annual tax revenue from cigarettes alone was about USD 765 million.[49] Allocating additional revenues generated specifically from "sin taxes" to health could sustain malaria elimination without displacing the existing pool of government funding from other sectors or from other health priorities.

Other means of increasing domestic financing include the use of innovative financing mechanisms such as health bonds, diaspora bonds, "Debt 2 Health," airline taxes, and financial transactions taxes to provide additional revenue. Social impact bonds or pay-for-performance bonds are other promising innovations instruments that have been used to raise financing for health and other sectors such as education and environment.[50] Analysis of their applicability or feasibility for implementation in Sri Lanka, however, is beyond the scope of this study.

g Other private sector partners such as Microsoft Sri Lanka, HSBC, Chevron, and Singer are potential development partners in Sri Lanka.

Discussion and conclusion

This study found that the cost of keeping Sri Lanka malaria-free in 2015 was approximately USD 0.57 per capita. The hypothetical cost of resurgence far surpassed the cost to sustain current efforts. The median ROI for malaria POR was estimated to be 13.3 to 1, far exceeding the threshold on returns for high-impact health investments.[h] This ROI is likely to be even higher if the indirect effects of malaria on society were included such as the effects on education, cognitive development, and tourism, which some studies have reported to be areas that malaria can significantly impact.[30–37]

Although the probability of malaria resurgence is difficult to predict, historical evidence from Sri Lanka and other countries suggest that weakening vigilance and declining financing is likely to result in a rebounding of malaria cases.[6] In this study, given that the cost of resurgence is almost 13 times the cost of POR, a conservative resurgence scenario with a 20% less probability would still exceed the cost of investing in POR. If other resurgence scenarios were considered—such as the post-1963 epidemic with 537,705 cases and the 1987 epidemic with 676,569 cases—the corresponding cost of resurgence would be much higher.

There are several limitations to the methods employed, as well as the data used in this study. Obtaining accurate cost data, particularly in an integrated health system, is a challenge. The resources for malaria were shared across other public health programs, which led to difficulty in attributing resources to malaria alone. Activities for malaria were also paid for through a combination of government and Global Fund resources. Most provincial level staff were paid using government funds, while several central AMC staff were funded through a Global Fund grant. In addition, malaria surveillance staff were often used for other public health functions, such as dengue surveillance.

Costs were apportioned using self-reported hours, potentially introducing a reporting bias to the estimates. A time and motion study would be an ideal methodology for estimating these costs by monitoring the time and resources spent on each activity. However, the time and resources available for this research did not allow us to employ this method.

Estimates of the cost of a hypothetical resurgence scenario were based on data from 1999. We acknowledge the difficulty in accurately predicting the timing, scale, and magnitude of resurgence in case funding is withdrawn; however, the probability of resurgence is high in Sri Lanka based on historical evidence, the continued presence of malaria vectors, and malaria importation from other endemic countries. Nonetheless, while keeping Sri Lanka malaria-free undoubtedly generates large returns, our actual estimate of the cost of POR and cost of resurgence should be applied and extrapolated with caution.

There are currently no global recommendations on the specific mixes of interventions needed for malaria elimination and POR including the effectiveness and cost-effectiveness of different approaches to POR. The default strategy for POR in Sri Lanka has been based on a detailed understanding of the malaria epidemiology in the country combined with pragmatic decision-making in a resource-limited context. The AMC has largely suspended vector control activities since achieving national elimination but is implementing several methods of epidemiological and entomological surveillance. Our estimates of costs and ROI are primarily based on the assumption that the current strategy in Sri Lanka will be maintained. Nevertheless, without a mathematical model to assess the epidemiological and economic efficiency of the intervention mix, it is difficult to recommend optimization strategies or to judge if further cost savings can be accrued.

Quantifying the cost of resurgence is challenging because the benefits of investing in malaria POR extend beyond the boundaries of health. A few distal benefits estimated in this study provide a glimpse of the enormity of the averted costs to the economy if investments in malaria are sustained. There are, however, other positive externalities from malaria elimination, such as health system strengthening and the promotion of regional health security, that we do not explore here.[15,52] It is critical, whenever possible, to recognize all direct and indirect costs and the impact of resurgence in order to determine the value of continued investments in malaria POR.

Reduced funding for malaria will severely impact the national program and its activities including management and leadership, an important requirement for malaria POR as evidenced by history.[6,53] Despite the strong health benefits associated with keeping Sri Lanka malaria-free, which justifies continued investment in POR, the country is likely to face a considerable gap in funding. In 2016, Sri Lanka's Global Fund grant under the new financing mechanism was signed with an approved amount of USD 7,047,704 for 2016–2018.[54] Sri Lanka is expected to receive an average of USD 2.4 million annually over three years, which is 37% less than the amount disbursed by the Global Fund in 2014.[4] The large difference in funding, if left unfilled, could jeopardize the malaria program's progress and place the country at risk of resurgence.

Waning donor commitment and shifting of government funds away from malaria are imminent threats that need to be addressed through high-level advocacy to policy makers and donors. This investment case provides evidence for the benefits of continued prioritization of funding for malaria, and can be used to develop an advocacy strategy for increased domestic and external funding. Sri Lanka is on the brink of making history and the malaria program needs to be supported to ensure that its recent success is sustained and that history does not repeat itself.

h Mills and Shilcutt (2004) estimate a benefit-cost ratio of investment in malaria control to be between 1.9 to 4.7.[51]

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Annexes

Annex 1. Persons interviewed

Office	Name	Position
Anti-Malaria Campaign, Sri Lanka Ministry of Health, Nutrition and Indigenous Medicine	Risintha Premaratne	Acting Director
	Kumudu de Alwis	Parasitologist
	Devika Shiromanie	Information, Communication and Technology Assistant
	R.D.J. (Jeevanie) Harishchandra	Entomologist
	H.M.P. (Mihirini) Hewapathirane	Entomologist
	Upeka Attanayaka	Global Fund Finance Supervisor
	W.P.R. Kurera	Global Fund Management Assistant
	Saumya	CCP Assistant
	H.P.R. (Priyani) Darmawardene	Medical Officer
	Manonath Marasinghe	Medical Officer
	H.M.I. Ajantha	Chief Clerk
	G. Subramaniam	Deputy Director for Finance/Accountant
	Various staff (30)	Various positions
Puttalam Regional Malaria Office	D.A.R. (Asoka) Premasiri Dannoruwa	Regional Malaria Officer
	Various staff (10)	Various positions
Anuradhapura Regional Malaria Office	S.R. (Ravindra) Jayanetti	Regional Malaria Officer
	Various staff (9)	Various positions
Jaffna Regional Malaria Office	Arumainayagam Jeyakumaran	Regional Malaria Officer
	Various staff (11)	Various positions
Ampara Regional Malaria Office	M.B.R. (Rasika) Hasantha	Regional Malaria Officer
	Various staff (11)	Various positions
Hambantota Regional Malaria Office	B.S.L. (Lalanthika) Peris	Regional Malaria Officer
	Various staff (12)	Various positions
Institute for Health Policy	Ravi Rannan-Eliya	Director
	Shanti Dalpatadu	Senior Fellow
	Nilmini Wijemanne	Research Associate
	Sarasi Amarasinghe	Research Officer
	Nirmali Sivapragasam	Research Associate

Annex 2. Costing assumptions and methodology

Population numbers

We used 2014 mid-year population estimates by district published by the Sri Lanka Department of Census and Statistics.

Personnel time

Personnel times were all self-reported. We interviewed one person or staff member from each position to determine his or her time allocations by malaria activity. We then applied the time allocation of the staff member we interviewed to all staff members with the same designation. For certain positions where multiple people shared the same designation but conducted very different work activities (e.g., AMC medical officers), each person's time allocation was determined separately and used in the costing.

When a particular RMO staff member was not available, the regional malaria officer was interviewed instead.

Cars and other motor vehicles

We used the unit costs and year of purchase found in records of the Global Fund for the costing of cars and other motor vehicles. When a match between the AMC or RMO records and Global Fund records was not found, the next closest match was used.

For time allocations of cars and other motor vehicles, we used the time allocations reported by the personnel who use them or are in charge of the vehicles' maintenance and care.

Computers, printers, photocopiers, and other equipment

We used the equipment inventory provided by the AMC as basis for costing the functioning computers, printers, fax machines, and photocopiers at the AMC. If a particular computer or computer equipment had a designated owner, we applied that personnel's time allocation to the equipment. For computers and computer equipment that are used by multiple staff, we used the average of their time allotments.

We asked the RMOs to provide list of all their functioning computers and computer equipment. We asked them to provide time allotments for all the computers and computer equipment. When no time allotments were provided, we used the average of the self-reported time allotments of all the staff that use the computers or computer equipment. We used the unit costs and year of purchase found in Global Fund records for the costing of computers and computer equipment. When a match between the AMC or RMO records and Global Fund records could not be found, the next closest match was used.

Buildings

We did not include the costs of buildings, office spaces, and laboratory space in the costing because no records of construction costs were available. However, building maintenance costs (e.g., elevator maintenance, building repairs, etc.) were included.

Furniture

Because prices for most RMO furniture were not available, we created a basic package of furniture composed of office tables and chairs, cupboards and drawers, metal safe, ceiling fans, etc. The quantity of each item included in the package was based on the average quantity reported by the five RMOs sampled. Costs for each item were based on furniture prices from Global Fund records. When two or more prices for each item were available in the Global Fund records, we chose the most recent price available. The year of purchase used was the midpoint of the years from which the unit costs were taken.

Depreciation

To calculate the depreciated value of capital resources, we divided the original total cost of the good by an annuity factor (Table A1) based on a 3% discount rate and the good's ULYs (Table A2) and multiplied that value by the remaining ULYs.

Depreciated value = (Original Total Cost/Annuity Factor)· Remaining ULYs

Remaining ULYs = ULYs - (2014 - Year of Purchase)

Table A1. Annuity factors at 3% discount rate*

Useful Life Years	Annuity factor
1	0.971
2	1.913
3	2.829
4	3.717
5	4.58
6	5.417
7	6.23
8	7.02
9	7.786
10	8.53

*Taken from Drummond, Michael F., et al. Methods for the Economic Evaluation of Health Care Programmes. 4th ed. Oxford, UK: Oxford University Press, 2015.

Table A2. Useful life years for capital goods and equipment*

Capital goods	Useful Life Years
Motorcycles	5
Vehicles	10
Computers	5
Microscopes	10
Buildings	20

*The ULYs used are based on the recommendations in the Bill & Melinda Gates Foundation's "Guidance for Estimating Cost for Malaria Elimination Projects."

Services

To estimate time allocation for buildings and office spaces, we used the average of the time allocations of all the personnel who occupy the building or space.

Annex 3. Cost categories and activities

Categories	Activities
Prevention and vector control (PVC)	Environmental management
	Targeted biological control
	Personal and community protection (LLINs and IRS)
	Chemical larviciding
Diagnosis (D)	Rapid diagnostic test
	Molecular diagnosis and confirmation
	Quality assurance
	Case management
Treatment and prophylaxis (TP)	Chemoprophylaxis
	Passive case detection
	Provider training
Surveillance and epidemic management (SEM)	Active case detection
	Activated passive case detection
	Entomological surveillance
	Case investigation and response
	Epidemic response
	Surveillance training
	Private sector surveillance
Monitoring and evaluation (ME)	Internal ME
	External ME
	Health information system
	Periodic surveys
Information, education, and communication (IEC)	Private sector engagement
	Partnership development
	Behavior change communication programs
	Policy advocacy
	School-based education
	Operational research
Program management (PM)	Administrative training
	Capacity building
	Staff placement and recruitment
	Meetings
	Supervision and monitoring
	General administration

Annex 4. Malaria program in Sri Lanka

Sri Lanka's malaria elimination and POR strategy for 2014–2018 brings together (1) four strategic approaches that emphasize early and accurate case detection and treatment through active surveillance and (2) five crosscutting strategies that aims to ensure quality and efficiency in service delivery (Figure A1).

Figure A1. Schematic diagram of the strategic framework for malaria elimination and prevention of re-introduction in Sri Lanka[4]

Cross-cutting strategies	Main strategies
• Quality assurance • Strengthening IEC activities • Improving program management and performance • Engaging in operational and implementation research • Monitoring and evaluation	• Strengthening surveillance for malaria case detection • Maintaining skills for diagnosis and treatment • Strengthen outbreak preparedness, prevention, and response • Strengthen entomological surveillance and response through Integrated vector management

Treatment

Artemether-lumefantrine was adopted as the first line anti-malarial treatment for uncomplicated *Plasmodium falciparum* infections in 2007 (Table A1). All *P. falciparum* cases are hospitalized for three days to ensure compliance to treatment and to monitor cases for potential adverse events.

Since 2010, all military *P. vivax* patients are hospitalized for three days in military medical facilities throughout the country (Table A1). After their stay, military patients are kept within their barracks for two weeks to ensure compliance with a 14-day primaquine regimen, 0.25 mg/kg body weight, in addition to chloroquine for 3 days. In 2013, an immediate dose of 0.75 mg/kg body weight of primaquine was added to the treatment regimen. In addition, the AMC recommends that all members of large population groups from endemic countries who have come to reside in Sri Lanka be treated with 0.25mg/kg body weight of primaquine for 14 days as radical cure, upon detection of imported *P. vivax* infections within a group. Screening for G6PD deficiency is not currently done prior to administration of primaquine, but will be introduced likely in late 2016.

Since 2012, blood samples of all malaria cases reported in the country are genotyped and archived in order to identify sources of outbreaks that may occur in the future. The treatment of severe malaria is now injectable artemisinin followed by artemether-lumefantrine.

Table A3. Protocol for inpatients (*P. falciparum*, uncomplicated and severe malaria, and *P. vivax*)

Uncomplicated malaria (*P. falciparum*)	Hospitalization for 3 days with immediate dose of primaquine (0.75 mg/kg body weight) plus artemether-lumefantrine (20/120 mg)
Severe malaria (*P. falciparum*)	Hospitalization with injectable artesunate until patient can take medication orally (usually 3 days) after which a complete course of artemether-lumefantrine (20/120 mg) is given
Military	*P. vivax* patients hospitalized for 3 days in military medical facilities; patients are kept within their barracks for two weeks for 14-day primaquine regimen (0.25 mg/kg body weight) in addition to chloroquine for 3 days
Non-military	Primaquine for 14 days (0.25 mg/kg body weight) plus chloroquine for 3 days
Mixed infections	Artemether-lumefantrine (20/120 mg) for 3 days plus primaquine for 14 days as an inpatient for 3 days

Surveillance

The AMC conducts parasitological surveillance, including passive case detection (PCD), activated passive case detection (APCD),[i] and active case detection (ACD). PCD and APCD surveillance is provided at 372 hospital sites with facilities for microscopy. ACD is conducted in selected areas through mobile malaria clinics on a voluntary basis. The criteria for selection of ACD locations included past incidence of malaria, difficult-to-reach areas, areas with high malaria receptivity, and the presence of high-risk populations such as armed forces personnel and displaced persons. Patients with symptomatic malaria are most likely to present at hospital settings, while asymptomatic cases are targeted through mobile malaria clinics.

Entomological surveillance is routinely carried out to monitor vector control activity and insecticide effectiveness. Entomological surveillance techniques for adult mosquitoes include cattle baited net and hut traps, exit trap collections, insecticide spray sheet collections, and hand collections. Other activities conducted at regular intervals include: larval surveys to estimate larval densities; insecticide bioassays for IRS and LLINs; and insecticide susceptibility tests using wild caught mosquitoes. While most activities conducted during this period were funded by the Round 8 Global Fund grant, Provincial Councils funded additional days of entomological surveillance in some districts. Sri Lanka has been using the entire gamut of traditional techniques described in the literature, which is costly; however, under the NMSP 2014–2018, the AMC is developing a core set of optimal approaches for entomological surveillance and monitoring consisting of a combination of active and passive surveillance.

i APCD involves screening of all fever cases for malaria in health care facilities, regardless of whether malaria is suspected or patients have been referred by a clinician. In contrast, PCD involves screening of suspected malaria cases only after clinician referral.

Vector control

Sri Lanka traditionally relied heavily on IRS as a vector control measure since the eradication era, but with the adoption of the WHO's Global Malaria Control Strategy of 1992, reliance on IRS gradually waned in favor of insecticide treated nets. The AMC has implemented a spatial insecticide rotation approach to IRS since 1998. Rotation is still in place, although the use of insecticides for malaria control has dropped since 2009.

Between October 2011 and September 2014, 472,293 LLINs were distributed in malaria endemic areas throughout the country based on malaria receptivity and vulnerability. The areas and populations covered included high-risk areas with high vector densities, difficult to reach areas, malaria foci in the last 5 years, and displaced populations. Based on the current epidemiological situation, there is limited evidence and justification for use of IRS or LLINs when most of the cases are being reported in traditionally non-malarious areas. Under the new strategic plan, LLINs and IRS will be deployed focally in receptive areas and among vulnerable populations through an integrated vector management approach, informed by intensive entomological surveillance data. In addition, buffer stocks of LLINs and insecticides will be maintained for use in the event of an outbreak.

Larval control and environmental management is implemented in all malaria endemic areas using chemical and biological larviciding informed by entomological surveillance data. Temephos, and organophosphate larvicide, has been applied in a variety of settings where use of larvivorous fish was not feasible. The use of larvivorous fish, primarily guppies (Poecilia reticulata), has been promoted in all malaria endemic districts. Targeted biological larval control will continue under the new strategic plan as part of the integrated vector management approach.

Information, education, and communication

The AMC is also actively involved in raising community awareness and in community engagement. Through its headquarters and regional offices, the AMC and the Medical Officers of Health regularly conduct awareness-raising programs to a wide range of audiences, including personnel from other government sectors, school children, and travel agents through Malaria Day walks and special gatherings. In addition, the AMC raises awareness of malaria among the general public through print and electronic media.

Other services

Diagnostic services are available to travelers at ports of entry on a voluntary basis, and mandatory malaria screening among refugees and service personnel returning from UN peacekeeping missions is a routine activity. Chemoprophylaxis is also available at the two international airports, free of charge for travelers visiting malaria endemic countries. However, the uptake has been poor with only a small percentage of travelers availing of this service in 2013. The new strategic plan outlines approaches to improve uptake, including awareness-raising programs among the public, key government agencies, and the travel industry.

Because large areas of Sri Lanka remain both receptive and vulnerable to malaria transmission, importation is a major threat. Ports of entry, as well as labor-intensive activity sites and areas that rely on overseas migrant workers (e.g. construction sites, free-trade zones, new sea ports, and industrial parks) will be the focus of enhanced surveillance for malaria under the new strategic plan. The recently-adopted National Migration Health Policy of Sri Lanka will be used to guide the policy and strategy adjustments needed to deal with the influx of foreign labor and migration from highly malarious neighboring countries, such as compulsory screening of migrant labor upon arrival.

Supply chain for antimalarials

Artemisinin-combination therapies and RDTs are currently procured by UNICEF on behalf of the AMC. Although the Medical Supplies Department manages the national medicines supply chain, a parallel system for antimalarial products has been created and is managed by the AMC. The products are received by the AMC and stored at the central level. The provinces are allocated stocks based on a combination of past consumption and malaria risk. The products are stored at the RMOs and are supplied to the malaria mobile clinics which in turn treat patients who test positive for malaria. Antimalarials are not stocked in government or private health facilities. Providers are expected to notify the AMC upon a suspected or positive blood slide and the AMC dispatches the mobile malaria clinics to investigate and treat the case. There are plans to re-integrate the supply chain within the national system in the future.

The **Global Health Group** at the University of California, San Francisco (UCSF) is an 'action tank' dedicated to translating new evidence into large-scale action to improve the lives of millions of people. The Global Health Group's Malaria Elimination Initiative (MEI) was launched in 2007 to accelerate progress in countries and regions that are pursuing achievable and evidence-based elimination goals and paving the way to malaria eradication.

In partnership with other forward-thinking researchers, implementers, and advocates, the MEI works across global, regional, and national levels. We conduct operational research on surveillance and response, develop new tools and approaches for aggressive elimination, document and disseminate country experience, determine the costs of and financing needs for achieving elimination, build consensus, and influence policy and financing to shrink the malaria map. The MEI believes that global eradication of malaria is possible within a generation.

globalhealthsciences.ucsf.edu/GHG/MEI
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