Assessing Surveillance Elements of the Zanzibar Malaria Elimination Program to

Support Malaria Elimination in Zanzibar

by

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Thesis submitted in partial fulfillment of
the requirements for the degree of
Master of Science in the Duke Global Health Institute
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ABSTRACT

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Abstract

Though significant progress has been made through control efforts in recent years, malaria remains a leading cause of morbidity and mortality throughout the world, with 3.2 billion people at risk of developing the disease. Zanzibar is currently pursuing malaria elimination through the Zanzibar Malaria Elimination Program (ZAMEP), and is working toward a goal of no locally acquired malaria cases by 2018. A comprehensive and well functioning malaria surveillance program is central to achieving this goal. Under ZAMEP's current surveillance strategy, District Malaria Surveillance Officers (DMSOs) respond to malaria case notifications through the reactive case detection (RACD) system. Three malaria screening and treatment strategies are undertaken in response to this system, including household-level (HSaT), focal-level (FSaT), and mass-level (MSaT). Each strategy is triggered by a different case threshold and tests different-sized populations. The aims of this study were to (1) assess the cost effectiveness of three malaria screening and treatment strategies; (2) assess the timeliness and completeness of ZAMEP's RACD system; (3) and qualitatively explore the roles of DMSOs.

Screening disposition and budget information for 2014 screening and treatment strategies was analyzed to determine prevalence rates in screened populations and the cost effectiveness of each strategy. Prevalence rates within the screened population

varied by strategy: 6.1 percent in HSaT, 1.2 percent in FSaT, and 0.9 percent in MSaT. Of the various costing scenarios considering cost per person screened, MSaT was the most cost-effective, with costs ranging from $9.57 to $12.57 per person screened. Of the various costing scenarios considering cost per case detected, HSaT was the most cost-effective, at $385.51 per case detected.

Case data from 2013 through mid-2015 was used to assess the timeliness and completeness of the RACD system. The average number of RACD activities occurring within 48 hours of notification improved slightly between 2013 and the first half of 2015, from 90.7 percent to 93.1 percent. The average percentage of household members screened during RACD also increased over the same time period, from 84 percent in 2013 to 89.9 percent in the first half of 2015.

Interviews with twenty DMSOs were conducted to gain insights into the challenges to malaria elimination both from the health system and the community perspectives. Major themes discussed in the interviews include the need for additional training, inadequate information capture at health facility, resistance to household testing, transportation difficulties, inadequate personnel during the high transmission season, and community misinformation.

Zanzibar is now considered a low transmission setting, making elimination feasible, but also posing new challenges to achieving this goal. The findings of this study provide insight into how surveillance activities can be improved to support the goal of malaria elimination in Zanzibar. Key changes include reevaluating the use of MSaT activities, improving information capture at health facilities, hiring additional DMSOs during the high transmission season, and improving community communication.

Dedication

I dedicate this thesis to my family and friends who have supported me throughout my graduate work. I especially want to thank my husband Bruce who encouraged me to pursue graduate education and has been my cheerleader through the process.

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Acknowledgements

I wish to thank my committee members for their wisdom and guidance throughout the thesis process. Thank you, Dr. Randall Kramer, my committee chair, for your input and support. Thank you, Dr. Marc Jeuland and Dr. Mina Silberberg for agreeing to serve on my committee and for your comments along the way.

I would also like to thank RTI International and the Zanzibar Malaria Elimination Program (ZAMEP) for allowing me to work with them and use their data. In particular, I would like to thank Dr. Jeremiah Ngondi and Humphrey Mkali for their guidance and support.

1. Introduction

1.1 Global Malaria Burden

Though significant progress has been made through control efforts in recent years, malaria remains a leading cause of morbidity and mortality throughout the world, with 3.2 billion people at risk of developing the disease (World Health Organization, 2013). In 2013, 198 million cases of malaria occurred, with 584,000 cases resulting in death (World Health Organization, 2014). Malaria disproportionally affects Sub-Saharan Africa, where 90 percent of worldwide malaria deaths occurred in 2015 (World Health Organization, 2016). Malaria control efforts in Sub-Saharan Africa have increased dramatically over the past decade to address this burden. As of 2013, 48 percent of the Sub-Saharan African population was protected by at least one vector control method (World Health Organization, 2014).

Vector control is an important strategy for reducing malaria transmission. Common vector control measures include insecticide treated nets (ITNs), larvicide, and indoor residual spraying (IRS). Resistance to insecticides used for vector control have been reported in 49 of 63 countries monitoring resistance (World Health Organization, 2013). Pyrethroid resistance is most commonly reported; it is also the pesticide most commonly used for vector control (World Health Organization, 2014). Presently, pyrethroids are the only class of insecticides recommended for use in ITNs (World Health Organization, 2016). Thirty-nine of the reporting countries reported resistance to two or more insecticide classes, with some countries reporting resistance to all four classes (World Health Organization, 2016).

Increasing resistance is not limited to insecticides. Antimalarial drug resistance has been reported in southeast Asia (World Health Organization, 2013). Artemisinin-based combination therapy (ACT) is recommended to treat uncomplicated malaria caused by *Plasmodium falciparum*, the most common malaria parasite in Africa (World Health Organization, 2016). ACT consists of artemisinin combined with a drug from another class, including lumefantrine, mefloquine, amodiaquine, sulfadoxine/pyrimethamine, piperaquine and chlorproguanil/dapsone (Malaria Consortium, 2016). Artemisinin resistance emerged independently in Cambodia, Lao People's Democratic Republic, Myanmar, Thailand, and Vietnam (World Health Organization, 2016). Despite this resistance, most patients treated with ACT were cured if there was no resistance to the partner drug (World Health Organization, 2016). Multi-drug resistance has, however, developed in both Cambodia and Thailand (World Health Organization, 2016). Increasing resistance illustrates the urgency of eliminating malaria, where possible, before available control and treatment strategies are no longer effective.

1.2 Malaria Elimination

Malaria elimination is defined by the World Health Organization (WHO) as "the interruption of local mosquito-borne malaria transmission, i.e. the reduction to zero of the incidence of malaria infection in a defined geographical area (World Health

Organization, 2015)." Elimination is third in a series of four country program phases working toward malaria-free status: control, pre-elimination, elimination, and prevention of reintroduction (World Health Organization, 2015).

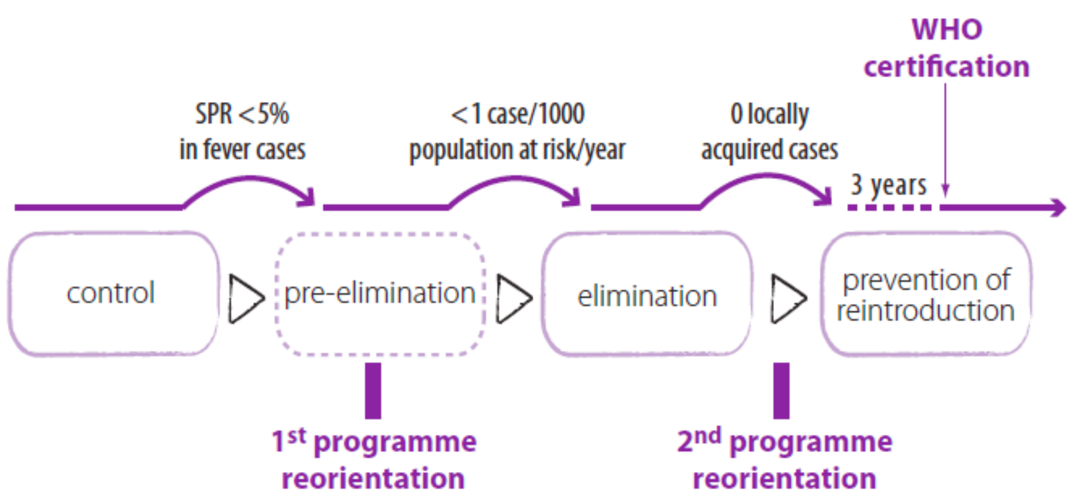

Figure 1: Malaria Program Phases and Milestones on the Path to Malaria Elimination, Source: World Health Organization, 2007

Malaria control focuses on reducing malaria morbidity and mortality with interventions such as bednet distribution, IRS, environmental sanitation activities, mass drug administration, and improved access to testing and treatment. In malaria elimination, the burden of disease has been significantly reduced, and efforts are focused on identifying all malaria cases to prevent onward transmission.

When determining whether or not to pursue elimination, technical, operational, and financial feasibility must be considered (Moonen et al., 2010). Technical feasibility considers the current malaria situation of the country and whether the tools available, such as vector control methods and antimalarial treatments, will be sufficient to sustainably interrupt transmission (Moonen et al., 2010). Operational feasibility looks at the administrative and programmatic capacity of the country to determine whether the technical aspects can be effectively managed and addressed (Moonen et al., 2010). Financial feasibility examines the costs of the technical and operational aspects involved and determines whether they are manageable or prohibitively expensive (Moonen et al., 2010). If all three aspects are considered feasible, elimination can be reasonably pursued.

Seventy-nine countries successfully eliminated malaria between 1945 and 2010, and 95 percent remained malaria-free (Chiyaka et al., 2013). These figures are encouraging to support additional elimination efforts, but it is important to acknowledge that challenges exist to remaining malaria-free, including reintroduction by travelers and decline in political and financial support for malaria programs. Surveillance can be utilized both to achieve elimination status and to maintain it through rapid reporting of imported cases to prevent onward transmission (Cotter et al., 2013).

1.3 Malaria Surveillance

Malaria surveillance systems are comprised of tools, procedures, people and structures that provide information on malaria cases (World Health Organization, 2012). According to the WHO, a malaria surveillance system should capture information that allows analysts to do the following: (1) identify areas or populations most affected by malaria; (2) identify trends in cases that require additional intervention; and (3) assess the impact of control measures (World Health Organization, 2012). Elements of an effective malaria surveillance system vary, depending on the phase of the malaria program (control or elimination) and the level of transmission (high-and-moderate or low).

Table 1: Malaria Surveillance in Different Transmission Settings and Phases of Control, Source: World Health Organization, 2012

	Control phase		**Elimination phase**
Transmission:	**High & moderate**	**Low**	**Very low**
Parasite prevalence (2-9 yrs):	>10%	<10%	
Incidence:	Cases and deaths common and concentrated in <5yrs	Cases and deaths less common distributed according to mosquito bite exposure	Cases sporadic
	Limited temporal variation	Variable within and between years Risk of epidemics	Imported cases may be high proportion of total
	Limited geographical variation	Geographical heterogeneity Concentrated in marginal populations	Focal distribution
Fevers:	Proportion of fevers due to malaria relatively large	Proportion of fevers due to malaria small	Proportion of fevers due to malaria very small (though may be high in certain foci)
Health facility attendance:	High proportion due to malaria	Low proportion due to malaria	
Vectors:	Efficient	Controlled efficient/ inefficient	Controlled efficient/ inefficient
Aims of programme:	Mortality & case reduction	Case reduction	Eliminate transmission
Surveillance system			
Resources:	Low expenditures per head Low quality and poor accesibility of services	Widespread availability of diagnostics and treatment	Resources to investigate each case
Data recording:	Aggregate numbers	Aggregate numbers Lists of inpatients and deaths → lists of all cases	Case details
Investigation:	Inpatient cases	Inpatient cases → all cases	Individual cases

In an elimination setting, surveillance efforts aim to identify all malaria cases (including asymptomatic cases) to stop local transmission. This can be done through passive case detection or active case detection. Passive case detection is the detection of malaria cases among people who went at their own initiative to a health facility to get treatment (World Health Organization, 2012). Active case detection is the detection by health workers of malaria infections at the community and household level among population groups that are considered to be high risk (World Health Organization, 2012). This study examines elements of the malaria surveillance system in Zanzibar, which includes both passive and active case detection components, and assesses them for financial and operational feasibility.

1.4 Malaria in Zanzibar

Zanzibar is a semi-autonomous territory of Tanzania and has its own president and parliament (BBC News, 2015). As such, it also has its own government ministries, including the Ministry of Health under which Zanzibar's malaria elimination efforts are based. Zanzibar is an ideal candidate for malaria elimination as a geographically isolated archipelago; this isolation limits the opportunities for malaria reintroduction from local endemic areas. It is primarily comprised of the islands of Unguja and Pemba in Tanzania. Unguja lies 22.5 miles off the coast of mainland Tanzania and is 54 miles long by 24 miles wide (Ingrams, 1967). Pemba is 25 miles northeast of Unguja and is 42 miles long by 14 miles wide (Ingrams, 1967). Each island is divided into districts; there are six districts in Unguja and four districts in Pemba (President's Malaria Initiative, 2012). Each district is divided into sub-districts, known locally as shehias.

Zanzibar has an equatorial climate, characterized by year-round high temperatures and humidity (Zanzibar Malaria Control Program, 2009). There are two rainy seasons; the long rains last from March to June and the short rains fall from October to December (Zanzibar Malaria Control Program, 2009). Malaria rates peak at the end of each rainy season, with the highest number of cases identified between May and July (Ministry of Health, 2011). *Plasmodium falciparum* accounts for 97 percent of malaria cases in Zanzibar (Zanzibar Malaria Control Program, 2009). Recent malaria control efforts have shifted endemicity patterns from hyper- to hypo-endemic (Zanzibar Malaria Control Program, 2009). Hyper-endemic diseases are constantly present at a high incidence or prevalence rate, whereas hypo-endemic disease incidence is sufficiently low that the population has little to no immunity against the disease (MediLexicon, 2016). As such, Zanzibar is now considered a low transmission setting.

Over the past century, malaria prevalence rates on the islands have fluctuated between less than one percent and over 70 percent (Zanzibar Malaria Control Program, 2009). Zanzibar has engaged in malaria elimination efforts twice before the current efforts but was unable to achieve and maintain low incidence rates due to political instability and subsequent funding unavailability (Smith et al., 2011; Zanzibar Malaria Elimination Program, 2014c).

In 1961, the World Health Organization (WHO), as part of their Global Malaria Eradication Program (GMEP), engaged in eradication efforts including the use of residual insecticides, larvicides, and chemoprophylaxis (Schwartz, Pener, Issa, & Golenser, 1997). Though the program was unable to eradicate malaria in Zanzibar, it did succeed in reducing prevalence rates from 74.2 percent in 1959 to 6.3 percent in 1969 (Jiddawi, 2011). This reduction in rates led malaria to no longer be considered a health concern, and the program was discontinued in 1968 (Schwartz et al., 1997). Prevalence rates subsequently rebounded to 45.8 percent in the following years (Jiddawi, 2011).

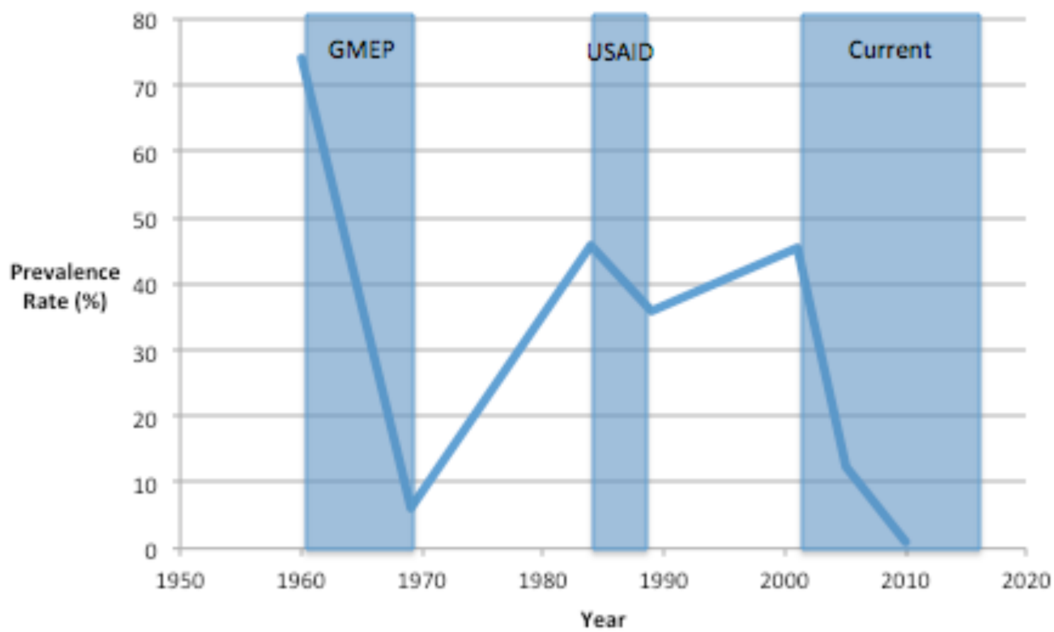

Figure 2: Historical Malaria Control and Prevalence in Zanzibar

In 1984, the United States Agency for International Development (USAID) funded a project of twice yearly residual spraying campaigns and chloroquine administration at health facilities (Zanzibar Malaria Control Program, 2009). This project was cancelled in 1989 after it failed to make significant changes in malaria prevalence on the islands. An evaluation of the project cited administrative problems, DDT resistance, and chloroquine resistance, as the reasons for the limited progress (Minjas JN, 1988). Prevalence rates during the USAID project did decrease to 36 percent during the project, but rebounded to 45.4 percent after its cancellation (Jiddawi, 2011).

In 2002, the Zanzibar Malaria Control Program (ZMCP), now known as the Zanzibar Malaria Elimination Program (ZAMEP), received an influx of funding from international organizations including the President's Malaria Initiative (PMI) and the Global Fund to Fight AIDS, Tuberculosis, and Malaria (Global Fund) and used the funds to implement a comprehensive control program (Zanzibar Malaria Control Program, 2009). This program included vector control measures, including IRS campaigns and distributions of long lasting insecticidal nets (LLINs), and development of case management and surveillance systems. In 2008, ZAMEP conducted an elimination feasibility assessment and decided to make malaria elimination its priority (Zanzibar Malaria Control Program, 2009). The program has been widely successful, with malaria prevalence rates dropping to less than one percent in 2013 (RTI International, 2013b). As stated in ZAMEP's 2013-2018 Strategic Plan, ZAMEP's present goal is to have no locally acquired cases of malaria in Zanzibar by 2018 (President's Malaria Initiative, 2014).

Currently, PMI and the Global Fund provide 96 percent of ZAMEP funding (Zanzibar Malaria Elimination Program, 2014b). If funding were reduced, it would have dramatic consequences on the malaria elimination effort. Paradoxically, the success of malaria control efforts jeopardizes future program funding. Per ZAMEP's website, “malaria has declined to a satisfactory level… [and] is no longer top of the list of leading public health problems in Zanzibar (Zanzibar Malaria Elimination Program, 2014a). If in the future malaria is no longer viewed as a public health priority, funding may be redirected to matters deemed more urgent than continued malaria control. This will likely lead to a repeat of past decades, where the absence of a sustained control program led to the reemergence of the disease.

1.5 ZAMEP Surveillance Mechanisms

Malaria surveillance in Zanzibar is conducted through both passive and reactive case detection (RACD) mechanisms. Passive surveillance is conducted through regular case reporting from health facilities (Nsubuga P, 2006). RACD is a subset of active case detection, in which individuals living near passively detected cases are screened and treated (Sturrock et al., 2013). Passive case detection in Zanzibar occurs at the health facility level through the Malaria Epidemic Early Detection System (MEEDS) (RTI International, 2013a). RACD is triggered when a case notification is received through MEEDS, thus beginning the Coconut Surveillance process (RTI International, 2013b). Coconut Surveillance maintains a database that contains information on all malaria cases diagnosed and treated at public health facilities in Zanzibar (RTI International, 2013b). Private health facilities began to be incorporated into the database in 2015 to make the surveillance system comprehensive of all health facilities in Zanzibar (Ngondi, 2015b).

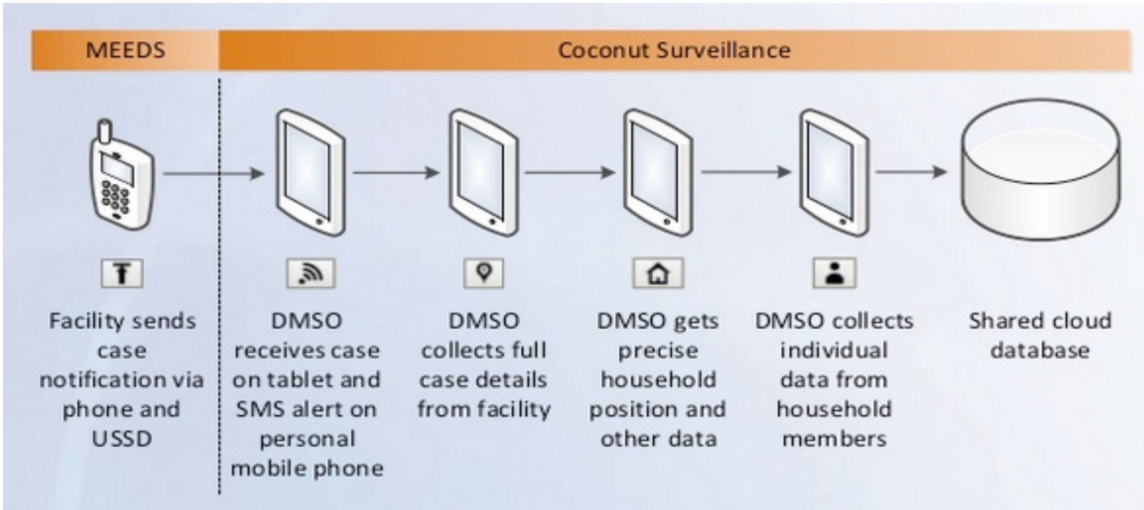

Figure 3: Malaria Surveillance Mechanisms, Source: Cressman, 2014

1.5.1 Malaria Epidemic Early Detection System (MEEDS)

Once a malaria case is identified at a health facility, the facility records information about the patient in the facility malaria case register (MCR). The facility then sends a malaria case notification (MCN) through unstructured supplementary service data (USSD) to ZAMEP using a mobile phone provided by ZAMEP. This text message contains information including an automatically generated case ID number, name of the patient, name of the health facility, and the district (RTI International, 2013b). The notification is relayed to the District Malaria Surveillance Officers (DMSOs) in the case's district. One DMSO then accepts the case and proceeds to the health facility to collect the patient's contact information in the MCR and conduct household follow-up. This step begins the RACD process.

Reports are also sent to ZAMEP weekly through USSD to summarize the facility malaria case information from the prior week. These reports include information on the week number, number of under-five total outpatient department visits, number of under-five positive malaria cases, number of under-five negative malaria cases, number of age five and above total outpatient department visits, number of age five and above positive malaria cases, and number of age five and above negative malaria cases (RTI International, 2013a).

1.5.2 Coconut Surveillance

Coconut Surveillance is a guided process for RACD. DMSOs access the Coconut application on their tablet and enter prompted information. Information collection begins once the DMSO receives and accepts a case notification and copies recorded patient data from the health facility's MCR. Once the initial data have been recorded, the DMSO travels to the patient's household to test all other household members for malaria and collects additional information on the patient, including recent travel history, household bednet usage, and more (RTI International, 2013b). A complete list of collected information can be found in Appendix 1. All case information collected through Coconut is uploaded to a central database to be monitored and analyzed by ZAMEP staff.

1.6 Study Aims

1. Assess the cost effectiveness of three malaria screening and treatment strategies. Three screening and treatment strategies are undertaken in response to reported malaria cases in Zanzibar. These strategies include household-level (HSaT),

focal-level (FSaT), and mass-level (MSaT) activities. Each activity has different associated costs and identifies different prevalence rates within the screened population. In a funding-limited elimination setting such as Zanzibar, it is important to determine which program activity identifies the most malaria cases in a cost effective manner so program activities can be sustained and the goal of elimination realized.

2. Assess the timeliness and completeness of the Zanzibar Malaria Elimination Program's (ZAMEP) reactive case detection (RACD) system. Timeliness and completeness of RACD are essential to identifying additional malaria cases rapidly to reduce transmission. Timeliness in the surveillance context is the amount of time from case notification to conclusion of follow up; in Zanzibar, follow up must be completed within 48 hours to be considered timely. RACD completeness refers to the percentage of household members tested for malaria during the follow up process; ideally, 100 percent of household members are captured. Timeliness and completeness of case follow up can be used as indicators to assess the effectiveness of the current RACD system and may indicate target areas for improvement to support malaria elimination.

3. Qualitatively explore the roles of District Malaria Surveillance Officers (DMSOs). DMSOs are integral to the RACD system, as they travel to health facilities and households to collect further case information and test household members to identify additional malaria cases. Interviews with twenty DMSOs were conducted to gain insights into their knowledge of challenges to malaria elimination both from the

health system and the community perspectives. This information can inform changes to the RACD system or larger malaria elimination strategy in Zanzibar to achieve elimination.

2. Literature Review

2.1 Costing Analyses of Malaria Screening and Treatment Strategies

Examining the costs of similar screening and treatment activities is helpful for assessing cost effectiveness of these activities in Zanzibar. Unfortunately, few such studies have been published. A 2015 study in Zambia examined the cost effectiveness of mass testing and treatment (MTAT) activities (Silumbe, Yukich, et al., 2015). It estimated the cost per RDT administered to be $4.39 and the cost per artemether-lumefantrine (AL) treatment administered to be $34.74 (Silumbe, Yukich, et al., 2015). The authors concluded that MTAT was cost effective compared to no MTAT, but population-wide mass drug administration would likely be more cost effective than MTAT (Silumbe, Yukich, et al., 2015).

A 2011 cost analysis in Kenya assessed the costs associated with school-based intermittent screening and treatment (IST) for malaria (Drake et al., 2011). The study estimated IST cost per child screened at $6.61 (Drake et al., 2011). Thirty-six percent of the costs were attributable to salary costs, 22 percent to RDTs, and 47 percent to redeployment of existing resources, including health worker time and use of hospital vehicles (Drake et al., 2011). The analysis concluded by noting that school-based IST is a relatively expensive malaria intervention, but the cost effectiveness is sensitive to the proportion of malaria positive children captured in the activity (Drake et al., 2011).

2.2 Timeliness and Completeness of Malaria Surveillance

Swaziland has a comprehensive malaria elimination program with elements similar to those in Zanzibar, including RACD. A 2013 study reflected upon the outcomes of RACD in Swaziland (Sturrock et al., 2013). This study found the probability of detecting a case was higher within the index case household than in neighboring households, at 3.3 percent compared to 0.9 percent (Sturrock et al., 2013). Additional cases were more likely to be detected if RACD was conducted within one week of case notification (OR 8.7, 95% CI 1.1-66.4) (Sturrock et al., 2013). The study also found that additional cases were more often identified if the house had not been sprayed with insecticide, suggesting IRS has a protective value. The study concluded by proposing future RACD efforts could be more timely and effective by focusing efforts on individuals living near index cases whose houses had not been sprayed with insecticide (Sturrock et al., 2013).

Another analysis conducted in Swaziland found that 92 percent of notified cases were followed up within 48 hours in 2015 (Malaria Elimination Group, 2015). It also found that 90 to 95 percent of secondary malaria cases were found within the index case household (Malaria Elimination Group, 2015).

Researchers in Zambia found that malaria prevalence in household members of passively detected cases was 8 percent, compared to 0.7 percent in control households (Stresman et al., 2010). A study in Peru found that RACD conducted within a 100 meter radius of households with a history of malaria in the past month identified cases at rates 4.3 times higher than passive surveillance alone (Branch et al., 2005). These findings further support conducting RACD activities in households near index cases.

2.3 Qualitative Studies of Health Workers in Malaria Control

A 2010 Uganda study on rapid diagnostic testing (RDT) conducted by community health workers, referred to locally as community medicine distributors (CMDs), examined perceptions of the CMDs and potential barriers to RDT adoption. Communities trusted CMDs for their voluntary service and the perceived effectiveness of the antimalarial drugs they provided (Mukanga et al., 2010). The study also noted that higher education of the CMDs corresponded to higher community acceptance. CMDs discussed challenges regarding transportation for case follow up and collection of supplies, adults demanding to be tested, and caregivers demanding their children be treated instead of referred (Mukanga et al., 2010). CMDs also noted concerns within the community that the blood collected for malaria testing would instead be tested for HIV or used for witchcraft. Some community members believed the testing procedure would infect their children with HIV. The study concluded that behavior change communication should be utilized to improve program acceptability and effectiveness.

The 2015 study of MTAT conducted by CHWs using RDTs in Zambia discussed above also noted challenges encountered by the CHWs (Silumbe, Chiyende, et al., 2015). These challenges included inadequate transport, the need to cover long distances, problems with PDAs, and inadequate compensation and supplies (Silumbe, Chiyende, et al., 2015). CHWs reported people refusing to be tested because they believed the blood would be used for satanic rituals, sold, or tested for HIV. The study also found MTAT achieved only modest reductions in prevalence and health facility incidence (Silumbe, Chiyende, et al., 2015). The authors concluded by stating increased community sensitization for mass treatment activities would improve the coverage and acceptance of future campaigns.

3. Costing Analysis

3.1 Methods

3.1.1 Procedures

The costing analysis was conducted by collecting information on ZAMEP screening and treatment activities performed in 2014. Three different screening and treatment strategies were utilized. Household screening and treatment (HSaT) was conducted when a single case was identified at a health facility (Ngondi, 2015a). A DMSO would then visit the household to test the remaining household members and provide treatment when additional cases were identified. Focal screening and treatment (FSaT) was conducted when five cases were identified within a village in a seven-day period, either through HSaT, at health facilities, or through a combination of HSaT and health facility activities (Ngondi, 2015a). Once five cases were identified within a village, FSaT activities occurred to test all village members for additional cases and provide treatment when necessary. Mass screening and treatment (MSaT) was conducted when ten cases were identified within a shehia in a seven-day period, either through HSaT, at health

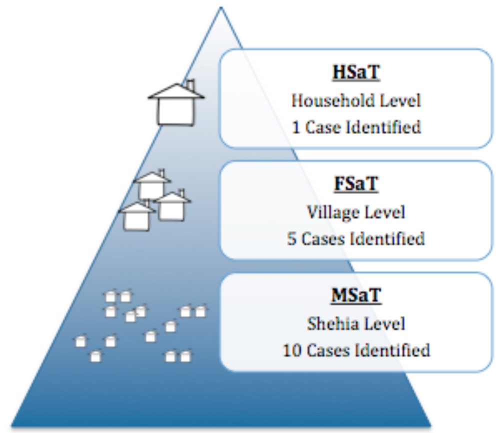

Figure 4: Screening and Treatment Strategies

facilities, or through a combination of HSaT and health facility activities (Ngondi, 2015a). Once ten cases were identified within a village, MSaT activities occurred to test all shehia members for additional cases and provide treatment when necessary.

Individual budgets for each FSaT and MSaT activity were collected by the author from ZAMEP staff to capture information on costs of each activity. These costs included per diems, in-kind costs, communication, fuel, data, and commodities. Information on total population examined and total positive cases identified were also captured through activity records to calculate the prevalence rate for each activity. HSaT costing information was collected from ZAMEP staff and captured recurring costs, such as DMSO salaries and commodities used in HSaT activities, as well as annual costs, including health facility MCRs and DMSO diaries. Information on one-time costs, including motorbikes and tablets, was collected but not included in the costing analysis. Information on total population examined and total number of cases identified was captured through Coconut to calculate the prevalence rate of populations captured by HSaT activities. This costing information was then entered into a spreadsheet created by the researcher to calculate the cost per person screened and cost per case detected for each screening and treatment strategy.

3.1.2 Measures

Costs were calculated for each of the three screening and treatment activities as cost per person screened and cost per case detected. Additionally, for FSaT and MSaT activities, costing simulations for three different case identification scenarios were conducted: one scenario in which all cases were identified through HSaT, one scenario in which half of the cases were identified through HSaT, and one case where none of the cases were identified through HSaT. For the purposes of this analysis, cases not identified through HSaT are those identified at a health facility. These costing simulations were conducted to illustrate the range of possible costs for each screening and treatment strategy in real-life scenarios, as the current activity setup allows for FSaT and MSaT activities to be triggered by a combination of HSaT and health facility-identified cases. The proportion of cases identified by HSaT versus at health facilities has costing implications, as shown in the analysis below.

3.1.3 Data Analysis

Data collected from the reviewed documents were entered into the Excel spreadsheet created by the researcher to assess the cost effectiveness of screening and treatment strategies. Cost per person screened and cost per case detected for each screening and treatment strategy were automatically generated by the formulas set up in the spreadsheet. FSaT and MSaT cost per person screened and cost per case detected were further analyzed by three case identification scenarios; these figures were automatically generated by the formulas set up in the spreadsheet.

3.2 Results

In 2014, 6399 household members were tested in HSaT activities. Of those tested, 392 additional cases were identified, for a prevalence rate of 6.1 percent. The cost of HSaT per person screened was $23.62. The cost of HSaT per case detected was $385.51. For a detailed breakdown of costs included in the analysis, please see Appendix 2.

In 2014, 8835 villagers were tested during FSaT activities. Of those tested, 104 cases were identified, for a prevalence rate of 1.2 percent. The cost of FSaT activities varied depending upon the scenario with which cases were identified. When all cases were identified through HSaT, the cost per person screened was $12.84 and the cost per case detected was $1090.59. When half the cases were identified through HSaT, the cost per person screened was $11.82 and the cost per case detected was $1003.86. When no cases were identified through HSaT, the cost per person screened was $10.80 and the cost per case detected was $917.13. A detailed breakdown of costs included in the analysis can be found in Appendix 3.

In 2014, 12,958 shehia members were tested during MSaT activities. Of those tested, 123 cases were identified, for a prevalence rate of 0.9 percent. The cost of MSaT activities varied depending upon the scenario with which cases were identified. When all cases were identified through HSaT, the cost per person screened was $12.57 and the cost per case detected was $1324.22. When half the cases were identified through HSaT, the cost per person screened was $11.07 and the cost per case detected was $1166.27.

When no cases were identified through HSaT, the cost per person screened was $9.57 and the cost per case detected was $1008.33. A detailed breakdown of costs included in the analysis can be found in Appendix 4.

3.3 Discussion

Of the various costing scenarios considering cost per person screened, MSaT was the most cost-effective, with costs ranging from $9.57 to $12.57 per person screened. The cost range depended upon the number of cases that were identified through HSaT to trigger the FSaT activity, with the lowest cost when no cases were identified through HSaT and the highest cost when all ten cases were identified through HSaT. These costs are consistent with the cost per RDT administered in MTAT activities in Zambia, at $4.39 (Silumbe, Yukich, et al., 2015). They also align with costs for school-based IST activities in Kenya, at $6.61 per child screened (Drake et al., 2011).

Table 2: Screening and Treatment Costs by Activity and Case Identification Scenario

All initial cases identified through HSaT

	HSaT	FSaT	MSaT
Cost per person screened	$23.62	$12.84	$12.57
Cost per case detected	$385.51	$1,090.59	$1,324.22

Half of initial cases identified through HSaT

	HSaT	FSaT	MSaT
Cost per person screened	$23.62	$11.82	$11.07
Cost per case detected	$385.51	$1,003.86	$1,166.27

No initial cases identified through HSaT

	HSaT	FSaT	MSaT
Cost per person screened	$23.62	$10.80	$9.57
Cost per case detected	$385.51	$917.13	$1,008.33

HSaT activities have a significantly higher cost per person screened, at $23.62, largely because fewer people are screened by this method. Additionally, significant costs such as DMSO salary and motorbike maintenance are captured in the HSaT costs. When looking strictly at commodities used to directly test and treat individuals, HSaT costs decrease to $1.61 per person screened.

Of the various costing scenarios considering cost per case detected, HSaT was the most cost-effective, at $385.51 per case detected. FSaT and MSaT costs per case detected range from $917.13 to $1324.22, respectively. The difference in cost-effectiveness per case detected in these scenarios can be explained by the difference in prevalence rates found in each population: 6.1 percent for HSaT, 1.2 percent for FSaT, and 0.9 percent for MSaT.

Table 3: Malaria Prevalence Among Screened Population by Activity

	HSaT	FSaT	MSaT
Prevalence rate	6.1%	1.2%	0.9%

In a funding-limited elimination setting such as Zanzibar, the cost per case detected is arguably the most important measure in the costing analysis, as it demonstrates the most cost-effective method to identify additional cases. Identifying additional cases is essential in an elimination setting to interrupt transmission of the pathogen. HSaT can be effectively utilized in combination with FSaT, as the prevalence rates of the populations captured in the activities are significantly higher than those of the general Zanzibari population. Prevalence rates in MSaT activities are consistent with those of the general Zanzibari population, indicating those activities are not more effective than Zanzibar-wide screening and treatment to identify malaria cases.

Another important consideration in elimination efforts is the testing method used to identify malaria cases. As Zanzibar is a low transmission setting, RDTs may not detect all malaria cases due to low parasitemia (Lindblade, Steinhardt, Samuels, Kachur, & Slutsker, 2013). RDTs are used for malaria diagnosis in HSaT and FSaT activities and some MSaT activities (Mkali, 2016). RDTs are also used at most health facilities, due to a lack of consistent electrical supply or trained personnel needed for microscopy (Mkali, 2016). RDTs are inexpensive and require little training to administer and read; as such, they are a useful tool for malaria diagnosis. Considering the goal of elimination, however, the feasibility of alternative testing methods should be examined and the probability of detection considered.

3.3.1 Recommendations

- Continue current HSaT activities. HSaT activities are the most cost effective option when considering the cost per case detected and identify cases at a prevalence rate of 6.1 percent, which is much higher than the prevalence rate of the general population. Reactive case detection is essential to identifying and treating additional malaria cases in a timely manner to limit further transmission.
- Continue FSaT activities triggered with five village-level cases. FSaT activities, though not the most cost effective option, identify cases at a prevalence rate of 1.2 percent, which is higher than the prevalence rate of the general population. This focused reactive case detection can help limit malaria transmission in identified hot spots.
- Discontinue or raise triggering threshold of MSaT activities. MSaT activities, though cost effective when considering cost per person tested in comparison to the alternative screening and treatment strategies, identify cases at a prevalence rate similar to that of the general population. This indicates that the current

shehia-based MSaT strategy is no more effective at identifying cases than a Zanzibar-wide screening and treatment strategy. For this reason, MSaT activities should either be discontinued, or the triggering threshold should be raised from ten identified cases within a shehia to a higher number. A triggering threshold of fifteen cases could be tested to see if prevalence rates in the screened population then exceed the prevalence rates of the general population.

- Conduct a feasibility assessment of alternative testing methods. Due to low parasitemia in low transmission settings such as Zanzibar and reduced RDT sensitivity with low parasitemia, alternative testing methods should be assessed to detect asymptomatic malaria cases, reduce further transmission, and achieve the goal of malaria elimination.

4. RACD Timeliness and Completeness

The above cost analysis affirmed the value of HSaT for identifying additional malaria cases in Zanzibar. HSaT is conducted during RACD. To examine the effectiveness of the current RACD system, timeliness and completeness of case follow up are analyzed below.

4.1 Methods

4.1.1 Procedures

RTI maintains a database that contains information on all malaria cases diagnosed and treated at public health facilities in Zanzibar. Private health facilities are also currently being integrated into the system (as of early 2015). Additionally, RTI collects data on RACD through their Coconut Surveillance system. This study used existing data from these sources to complete modules of an evaluation tool developed by the University of California, San Francisco (UCSF), and modified by the researcher to be appropriate for the Zanzibar setting.

RACD timeliness and completeness was assessed with information captured by Coconut. To assess timeliness, the number of RACD events that occurred within 48 hours of notification were divided by the total number of RACD events that occurred. To assess completeness, the number of individuals screened during RACD were divided by the total number of individuals living in the household. This information was collected on a monthly basis during 2013, 2014, and the first half of 2015.

4.1.2 Measures

To assess the timeliness and completeness of ZAMEP's MCN and RACD systems, a monitoring and evaluation tool developed by UCSF was adapted to be appropriate for Zanzibar. The tool included modules for synthesizing information on case investigation and reactive case detection.

4.1.3 Data Analysis

Data collected from the reviewed database was entered into the modified UCSF evaluation tool to identify trends in the surveillance metrics.

4.2 Results

In 2013, an average of 90.7 percent of RACD activities occurred within 48 hours of notification. This number improved slightly in 2014, when an average of 93.1 percent of RACD activities occurred within 48 hours of notification. An average of 93.1 percent of RACD activities occurred within 48 hours of notification in the first half of 2015.

In 2013, an average of 84 percent of the total household population was screened during RACD activities. This number improved slightly in 2014, when an average of 84.4 percent of the total household population was screened during RACD activities. This number improved yet again in the first half of 2015, when 89.9 percent of the total household population was screened during RACD activities.

4.3 Discussion

The percentage of RACD activities occurring within 48 hours of notification improved between 2013 and 2014 and held steady between 2014 and the first half of 2015. Follow up timeliness in Zanzibar was similar to that of Swaziland, where 92 percent of cases were followed up within 48 hours (Malaria Elimination Group, 2015). As shown in Table 1, while timeliness of follow up did dip slightly between April and June, it did not vary much between months overall. Timeliness of follow up may be affected by number of cases, which peak from May to July, and travel difficulties associated with the major rainy season, which runs from April to June. As timeliness did not widely vary throughout the year, however, other barriers to timely follow up are likely at play. Proposed by DMSOs in the interview discussion below, the biggest barrier to timely follow up is incomplete patient information collected at health facilities. If key information such as household ID or village name is not completed, follow up could be significantly delayed.

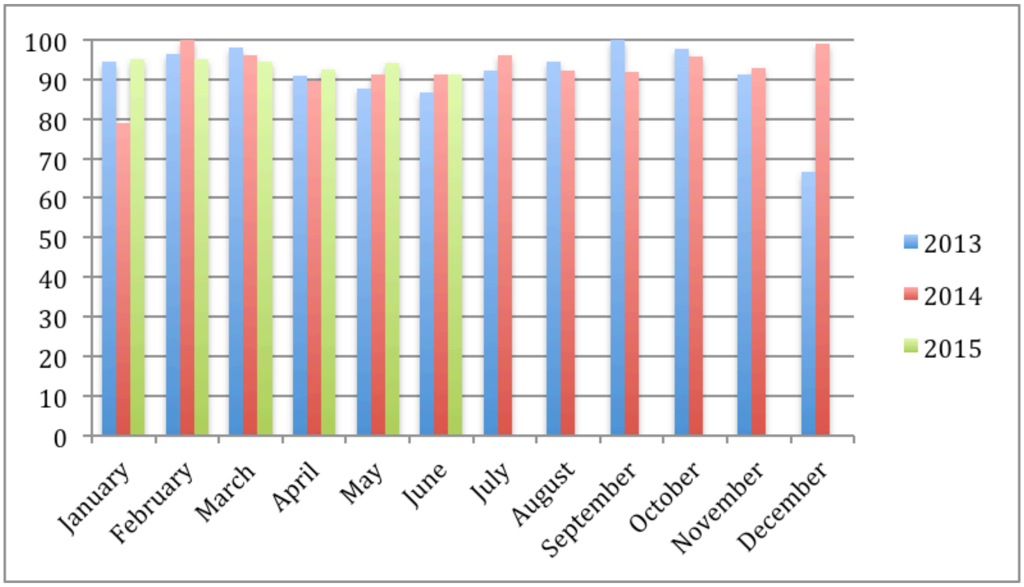

Figure 5: Percentage of Households Screened Within 48 Hours of Notification

Between 2013 and the first half of 2015, the average percentage of household members screened increased by six percent. This suggests that DMSOs have become better at communicating with households to schedule follow up visits to capture missing household members and have become more proactive at tracking missing household members to their places of work or school to complete screening.

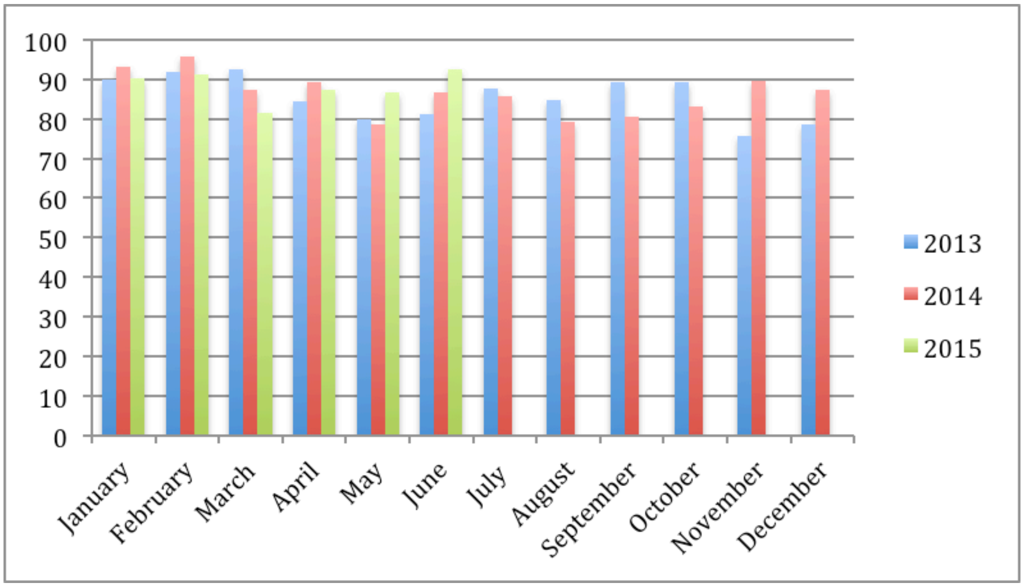

Figure 6: Percentage of Household Population Screened during RACD

4.3.1 Recommendations

- Provide additional training to health facility staff to improve MCR data collection. Incomplete patient information collection at health facilities is a significant barrier to timely household follow up. Health facility staff should be trained or retrained on the importance of recording all prompted patient data in the facility MCR to encourage complete data collection and support DMSO household follow up.
- Hire additional DMSOs during high transmission season to improve timeliness and completeness. Both timeliness and completeness decrease somewhat during high transmission season. Additional DMSOs should be hired during that period to distribute the workload burden and improve timely and complete household follow up.

5. DMSO Interviews

The cost analysis and examination of RACD timeliness and completeness above provided quantitative information about HSaT and RACD activities. The interviews below provide additional insight into the challenges associated with this work and how the surveillance system may be improved to maximize its effectiveness.

5.1 Methods

5.1.1 Setting

The majority of the interviews were conducted in the ZAMEP office in Unguja. Additional interviews were conducted in the ZAMEP office in Pemba and a centrally located Pemba hotel.

5.1.2 Sample

Twenty DMSOs were interviewed; two among each of Zanzibar's ten districts. Both DMSOs from each district were interviewed. All DMSOs who had worked in their position for longer than three months were eligible to participate; this cut off was decided upon so interviewed DMSOs would have performed their duties long enough to be comfortable in their roles as well as have enough experience to identify recurring challenges to their work. DMSOs are integral to the RACD system, as they travel to health facilities and households to collect further case information and test household members to identify additional malaria cases. They were chosen as the focus for these interviews for their knowledge of challenges to malaria elimination both from the health system and the community perspectives. Ethical approval was obtained from the Duke University Institutional Review Board (Protocol C0860).

- Receive malaria case notification (MCN) from health facility via text message to cell phone.
- Collect patient details from health facility within 24 hours of notification.
- Travel to household.
- Document Global Positioning System coordinates.
- Administer questionnaire.
- Take temperature of all household members.
- Test all household members with an RDT.
- Provide treatment to all household members who test positive.
- Use tablet PC to transmit results.

Figure 7: Summary of DMSO Tasks, Source: PATH, 2015

5.1.3 Procedures

Interviews were conducted on each island by a trained interviewer. The interviewer was fluent in Kiswahili and English. Interviewer training was conducted by the researcher three days prior to the first scheduled interview; training topics included the study aims and reasoning, probing exercises, and a review of the interview guide. The interview guide was developed by the researcher after consultation with RTI International staff; a copy of the interview guide can be found in Appendix 5. The interviews were recorded, transcribed, and translated by the interviewer.

All twenty DMSOs were interviewed to gain insight into their training, daily work and time management, job satisfaction, and improvements that could be made to the MCN and RACD systems, as well as community relationships. Interviews were conducted in Kiswahili and transcribed into Kiswahili and English for analysis. The

English transcriptions were analyzed using inductive reasoning and grounded theory to identify themes that emerged. The analysis was informed by study aims two and three, as well as bottom-up interpretations of the raw data (Thomas, 2003).

5.1.4 Measures

Open-ended interviews were conducted with the DMSOs to gather information on their motivations, prior work experience, daily workload and time management, work satisfaction, and improvements that could be made to the malaria case notification and reactive case detection systems, as well as community relationships. These interviews were conducted between 2 June 2015 and 25 June 2015 by a trained interviewer while the researcher observed.

5.1.5 Data Analysis

Inductive reasoning and grounded theory were used to create a codebook based on themes defined by the interview guide and that emerged from initial reviews of the DMSO interview transcripts (Saldana, 2009). The interview data collected was entered into NVivo 11, where it was coded. Sample codes include allowance, HIV testing, missing info, safety, and fuel shortage. Codes were grouped into categories to identify themes; these categories include training, health facility challenges, patient follow up challenges, technology challenges, supply challenges, community, and work. The complete codebook can be found in Appendix 6. Recommendations to improve the effectiveness of DMSOs and the greater malaria elimination program reflect the findings of this analysis.

5.2 Results

Major themes discussed in the interviews include additional training, health facility issues, follow-up challenges, transportation issues, personnel concerns, and community challenges. Some issues appeared exclusively in Pemba or Unguja, and some issues were identified on both islands.

DMSOs on both islands desired additional training. Topics identified for additional training on both islands include appropriate drug usage, tablet training on data entry and maintenance, and testing strategies and new technologies. Unguja DMSOs also wanted further training on malaria in general and surveillance.

The majority of DMSOs on both islands lamented that health facilities do not capture all the necessary information required to follow up on cases. Further, health facilities do not inform patients that DMSOs will be visiting their household to complete additional testing. DMSOs stressed the need to train both new and existing health facility staff on the proper malaria reporting procedures. A common concern among Unguja DMSOs is that patients are providing false information to health facilities, making case follow-up particularly difficult. Several Unguja DMSOs also stated concern that private health facilities would fabricate malaria cases for profit. Health facility phone issues were also identified in Unguja; DMSOs reported some facility phones were either broken or missing.

DMSOs in both Pemba and Unguja reported advising missing household members to report to health facilities for testing. Further, DMSOs occasionally did not have the drugs necessary to provide treatment, so positive household members were then advised to go to a health facility to acquire the appropriate drugs. Household members in both islands sometimes refuse to be tested, though this is more common in Unguja. The majority of Unguja DMSOs reported households often thought DMSOs were testing for HIV/AIDs; this misunderstanding was only reported by one DMSO in Pemba. Several Unguja DMSOs also cited travel to the mainland as a cause of loss to follow up.

DMSOs in both islands reported difficulty reaching households for testing, having to complete the journey by foot. Half the DMSOs also requested more regular motorbike maintenance. Several Unguja DMSOs were dissatisfied with their motorbikes, reporting that they were either too small or not fast enough. Timeliness of fuel disbursements was a concern on both islands. Additionally, nearly all the Pemba DMSOs reported fuel shortages for their work.

Nearly all the DMSOs cited network issues as a major problem and suggested switching networks from Airtel to Zantel. Pemba DMSOs reported not having enough airtime. Several DMSOs were also concerned about tablet damage during the rainy season.

Half the DMSOs reported concerns that the addition of private health facilities to surveillance reporting would make it difficult for them to complete their work. Several Unguja DMSOs requested that additional DMSOs be hired. Half the DMSOs also reported challenges balancing their DMSO work and their health facility responsibilities. Many DMSOs stated they do not get vacation, weekend, or holidays off. Relatedly, nearly all DMSOs wanted an allowance or additional incentives to work overtime. Another concern among DMSOs is that they do not feel included by ZAMEP. Half the Unguja DMSOs reported feeling that ZAMEP didn't care about their safety.

Pemba DMSOs generally reported stronger relationships with their communities. Nearly all Unguja DMSOs cited a need for additional malaria education in communities, with many reporting that people had heard there was no more malaria in Zanzibar. Unguja DMSOs suggested media campaigns as a method to improve community malaria education.

5.3 Discussion

Continuing education should be offered to DMSOs to improve their knowledge of malaria and the tools used for testing, treatment, and surveillance. DMSOs are eager to learn additional information on these topics and cited gaps in their knowledge as reasons for further training. If topics have been covered by previous training sessions, additional trainings could be offered as optional sessions so those who do not find a particular session useful to themselves will not be required to attend.

Proper drug usage and tablet technology were the most commonly requested topics for additional training. Proper drug administration is essential to providing quality treatment and reducing further malaria transmission. One DMSO recalled occasions where he called a contact at a health facility to confirm the appropriate treatment for a pregnant woman who tested positive for malaria.

> *"We as DMSOs are not trained in detail on treatment of malaria… for example, the case of pregnant women, we do not know what types of drug can be used. I have to contact someone at a nearby health facility asking which drug can be used for pregnant mothers. It is a disturbance, but if we know, it would be easy to know how to give medication to a pregnant mother."*

Further tablet training could improve DMSO efficiency and limit delays in information collection. One DMSO discussed how minor tablet issues can drain resources.

> *"Additional training on tablets [would be useful], and not just on case notification, but also on other tablet programs or how when minor problems happen we can fix it instead of being taught only to send cases or enter information. Sometimes we have minor problems and we don't know how to fix it, so we have to send it… to the big bosses for fixing. That happens because we are not trained, so we should be trained on how to fix."*

DMSOs commonly cited issues with information capture at health facilities. Information recorded in health facility MCRs was often incomplete and occasionally incorrect. This makes it difficult for DMSOs to complete proper follow up, particularly in a timely manner. One reason cited for inadequate information collection was new health facility staff who have not been trained on the proper case notification procedures. Trainings should be conducted with new and existing health facility staff to ensure proper recording of malaria case information in the MCR and timely system reporting.

Health facility staff also do not inform positive malaria patients that DMSOs will be visiting their household within 48 hours to test additional household members for malaria. Training health facility staff to relay this information to patients could help ensure more household members are available for testing during the DMSO visits, thus improving follow up completeness, as well as mitigate resistance to testing among household members. Unguja DMSOs reported that some household members do not want to be tested because they believe the DMSOs are testing for HIV/AIDS. Improving information on the roles of the DMSOs, beginning at the health facilities, should help diminish these concerns. Local leaders could also be a good resource to partner with to improve knowledge about the importance of DMSO household testing and foster community trust.

"I have to educate them that we don't test for HIV, we only test for malaria, and they say that there is no more malaria. We tell them that we still have malaria, but the malaria is reduced, and what we are trying to do is eliminate. They allow us after giving them education."

The belief that there is no more malaria in Zanzibar was widely reported in the communities from the Unguja DMSOs. Community education campaigns should be conducted to improve awareness about malaria elimination and dispel the notion that Zanzibar is currently malaria-free. In order for elimination to be achieved, communities need to be vigilant about continuing bednet use, IRS, and practicing environmental sanitation to reduce mosquito breeding sites. Community outreach will improve reception of DMSOs as well as support continued malaria control practices.

DMSOs commonly reported difficulty reaching households, even when the information recorded at health facilities was correct. Issues such as delayed or inadequate fuel disbursements and inadequate motorbike maintenance contributed to these delays. Another issue was poor condition of trails used to reach households, often causing DMSOs to complete their journey on foot. Poor trail conditions contribute to the need for increased motorbike maintenance and make timely case follow up more challenging, particularly during high transmission season where trail conditions are worst due to the rains.

"In my district, the area is very scattered, therefore it is a big challenge. You may go a distance from one area to another and the road and infrastructure is not good. In this case, sometimes you have to leave your motorbike somewhere and walk a far distance to follow the patient, most of all during the rainy season."

All household members are often not available when DMSOs arrive to conduct household testing. DMSOs often follow up on children at their schools, but farmers and fishermen are more difficult to locate. Repeated visits often find the same household members absent. DMSOs reported scheduling follow up visits to test household members, leaving their phone numbers for household members to call when they are available to be tested, and advising missing household members to report to their local health facility for testing. The latter option may contribute to lower reported case follow up completeness, as the DMSOs are unable to enter the test results of the missing household member to Coconut, even if they do later get tested at the local health facility.

The addition of private health facilities to the surveillance system is both welcomed and a cause for concern among DMSOs. Increased caseload diminishing their abilities to conduct timely and complete follow up was the most commonly cited concern. Several DMSOs explicitly requested additional DMSOs be hired to help manage the additional work, particularly during high transmission season. Half of the DMSOs reported difficulties balancing their DMSO duties with their health facility responsibilities; additional case follow up will only compound this issue. Another concern with private health facilities is that they will fabricate malaria cases for profit, increasing the DMSOs' workload and falsely increasing the reported malaria case statistics. Generally, however, DMSOs supported the inclusion of private health facilities into the surveillance system to help achieve malaria elimination.

There is general confusion about whether or not DMSOs are allowed time off from their work. Many DMSOs report working nights and weekends. Others report not taking vacation or spending much of their vacation time following up on cases.

> *"We DMSOs are different compared to other staff in the health facilities because the staff at the health facility gets vacation so that they get rest, but DMSOs don't have vacation. All the time, we are working. Even if you get vacation, you cannot do the activities you plan to do during your vacation without doing follow up… we don't have holidays. No Saturday, no Sunday. All the time you must do follow up of cases, therefore you find you have hard work."*

Due to these heavy work expectations, many DMSOs requested overtime allowances to compensate for their work.

> *"An allowance can help us to work more with all of our spirit… if you reflect on the tree that is cared for, you can harvest good fruit, but if you don't take care, you will get fruit but not in good quality. If we get care, then we will work more and we will love our work."*

This care extends beyond the granting of an allowance for overtime work. Unguja DMSOs cited an incident where a fellow DMSO was injured in an accident during the course of his duties. The DMSO's family had to pay for his treatment, and he received little to no support from ZAMEP. DMSOs believed ZAMEP should have covered the cost of his treatment and been more supportive through the recovery process. DMSOs are actively involved with the surveillance system and in communities. As such, they can provide valuable insight to improve ZAMEP's strategy and help make elimination achievable in Zanzibar.

5.3.1 Recommendations

- Provide DMSOs additional training on proper drug usage and tablet technology. Proper drug administration is essential to providing quality treatment and reducing further transmission. Additional training should be provided on proper drug usage to ensure DMSOs are familiar with the available treatments and appropriate situational distribution. DMSOs should receive further tablet training to ensure the devices are used optimally and maintained appropriately.
- Ask DMSOs to identify health facilities for additional staff case notification training. DMSOs commonly cited inadequate information capture at health facilities as a significant barrier to timely and complete case follow up. Though retraining staff at every health facility would be resource intensive, DMSOs could help identify facilities with the poorest adherence to proper case

notification procedures. These facilities could be targeted for additional training to improve information capture and system efficiency.

- Coordinate with DMSOs to ensure adequate drug supply. Drug shortages were reported by DMSOs, who then had to refer patients to health facilities to receive necessary treatment. It is not known if referred patients traveled to health facilities to receive this treatment. Untreated cases allow for further malaria transmission. By ensuring DMSOs have adequate drug supply, the likelihood of additional transmission due to lack of proper treatment is reduced.
- Improve timely fuel disbursement. Timely fuel disbursement will improve DMSO's ability to complete follow up in a timely manner as well as return to households, if necessary, to ensure follow up completeness.
- Increase fuel allowance in Pemba. DMSOs in Pemba consistently reported the existing fuel allowance was inadequate for them to complete their duties. Increasing the fuel allowance will allow DMSOs to complete follow up in a timely manner as well as return to households, if necessary, to ensure follow up completeness.
- Change network from Airtel to Zantel. Nearly every DMSO reported network issues. Connectivity issues delayed information transmission, which makes timely case follow up more difficult. Zantel was suggested as a more reliable wireless network on both Pemba and Unguja.

- Hire additional DMSOs in high burden districts during the high transmission season. Several DMSOs reported challenges with timely follow up due to high caseload burden during the high transmission season. It is likely this burden will increase as private health facilities are incorporated into the system. To distribute the caseload burden and ensure timely and complete follow up, additional DMSOs should be hired during the high transmission season.
- Purchase waterproof tablets when old tablets need replacement. DMSOs and their tablets are often exposed to the elements. This can damage their tablets, which can cause delays or incomplete information gathering. Purchasing waterproof tablets when old tablets need replacement will mitigate this issue in the future.
- Develop clear guidelines regarding vacation and overtime. There is general confusion among DMSOs as to whether or not they are allowed time away from their work. Developing clear guidelines regarding vacation and overtime will help clarify this issue.
- Provide a training workshop to DMSOs to clarify vacation and overtime policies. Official vacation and overtime policies should be communicated to DMSOs at a training workshop to ensure clarity and consistency and to improve job satisfaction.

- Improve community malaria education through media campaigns and local leader outreach. DMSOs reported some confusion among community members about the current malaria situation in Zanzibar as well as the roles of the DMSOs. Local leaders were often cited by DMSOs as good resources to include in community outreach efforts, as they are respected among their communities. Further, media campaigns may be an effective method for improving community knowledge on the current malaria situation in Zanzibar and reaching a widespread audience.

6. Conclusion

Progress toward malaria elimination in Zanzibar has been dramatic over the past decade. Zanzibar is now considered a low transmission setting, making elimination feasible, but also posing new challenges to achieving this goal. Surveillance plays a key role in this final push. Household and focal screening and treatment strategies should continue to be utilized to identify untreated malaria cases and reduce further malaria transmission. Timeliness and completeness of household follow up has increased over the past few years, reaching 93.1 percent of households followed up within 48 hours of case notification and 89.9 percent of the total household population screened. Though there is some room for improvement, these numbers capture and remove many of the opportunities for further transmission. DMSOs are central to surveillance efforts and can provide invaluable insight into how elimination efforts can be improved to achieve the 2018 goal of no locally acquired malaria cases. Zanzibar is in a good position, but efforts must not be relaxed until elimination has been achieved and meaningfully maintained, lest history repeat itself and malaria return to the islands with a vengeance.

Appendix 1: Information Captured in Coconut Surveillance (Khandekar, 2015)

Data Flow Step	Data Collected
Case Notification	• Case ID • Date of Creation and Final Edit • Facility Name • Patient Name • Shehia Name
Health Facility	• Date of Creation and Final Edit • Age • Contact Number • Patient Name • Head of Household Name • Travel History • Gender • Shehia Name • Village Name • Village Leader Name
Household	• Date of Creation and Final Edit • Household Geolocation • Last Date of IRS • Number of LLINs • Number of Sleeping spaces • Number of People in Household • Number of Household Members with fever • Number of Household Members with Malaria
Household Family Members	• Date of Creation and Final Edit • Patient Name • Age • Gender • Body Temperature • History of Fever • Travel History • Test Result • Sleep Under a Bednet

Appendix 2: Annual HSaT Costs by Item

Recurring Costs	**Amount**
DMSO salary	$42,328.29
DMSO meeting allowance	$7,760.28
RDTs	$5,951.07
Gloves	$752.39
Drugs	$1,843.65
Airtime	$10,582.20
Blood lancets	$376.20
Alcohol	$1,410.96
Motorbike fuel	$14,109.60
Motorbike maintenance	$22,779.94
Coconut maintenance	$42,328.79
Subtotal	*$150,223.37*
Annual Costs	**Amount**
HF MCR	$543.81
DMSO diaries	$352.74
Subtotal	*$896.55*
Grand Total	**$151,119.92**

Exchange rate: 1 USD = 1700.99 TSH as of 12/31/14

Appendix 3: 2014 FSaT Activities

Period	District	Shehia	Village	Total Population Examined	Total Positive Cases	Prevalence	HSaT(2.5)	HSaT (5)	Per Diems	In-Kind Costs	Communication	Fuel	Data	Commodities (incl treatment)	Commodities (excl treatment)
Quarter 2	South	Muyuni C	Kilima matangi	179	7	3.9	$693.83	$1,387.65	$975.91	$569.80	$123.46	$161.67	$235.16	$230.96	$198.04
	Central	Cheju	Kijini	332	12	3.6	$693.83	$1,387.65	$1,093.49	$439.56	$199.89	$129.34	$291.01	$423.75	$367.31
	North B	Donge mchangani	Kijitoni	152	18	11.8	$693.83	$1,387.65	$1,081.74	$610.50	$76.43	$52.91	-	$252.83	$168.17
		Bumbwini kidaazini	Pangatupu	594	7	1.2	$693.83	$1,387.65	$1,578.51	$700.05	$264.55	$161.67	$235.16	$690.11	$657.18
Quarter 3	Mkoani	Wambaa	Kwaazani	1056	18	1.7	$693.83	$1,387.65	$2,198.75	$1,058.21	$399.77	$452.68	$396.83	$1,252.98	$1,168.33
Quarter 4	North B	Donge Mchangani	Kijitoni	160	3	1.9	$693.83	$1,387.65	$1,081.74	$610.50	$76.43	$52.91	-	$191.13	$177.02
		Kidanzini	Pangatupu	440	1	0.2	$693.83	$1,387.65	$1,684.33	$700.05	$264.55	$161.67	$235.16	$491.51	$486.80
	North A	Mkwajuni	Uyagu	1075	4	0.4	$693.83	$1,387.65	$1,158.16	$504.68	$199.89	$258.68	$323.34	$1,208.16	$1,189.35
		Gomani	Mtakuja	872	1	0.1	$693.83	$1,387.65	$2,157.59	$1,041.93	$329.22	$698.43	$279.25	$969.46	$964.75
	West	Shakani	Minazi mikinda	111	1	0.9	$693.83	$1,387.65	$1,075.86	$439.56	$199.89	$129.34	$191.07	$127.51	$122.81
			Mbweni mji mpya	412	2	0.5	$693.83	$1,387.65	$2,486.82	$1,269.85	$258.68	$931.23	$235.16	$465.23	$455.82
	South	Kikadini	Mwenda wima	1403	2	0.1	$693.83	$1,387.65	$1,158.16	$504.68	$199.89	$258.68	$335.10	$1,561.64	$1,552.24
	Micheweni	Tumbe Mashariki	Kaliwa; Makadara; Mjini Tumbe	2049	28	1.4	$693.83	$1,387.65	$3,850.74	$1,701.27	$664.33	$905.37	$687.84	$2,398.64	$2,266.95
Total				**8835**	**104**	**1.2**	**$9,019.73**	**$18,039.45**	**$21,581.80**	**$10,150.66**	**$3,256.97**	**$4,354.57**	**$3,445.09**	**$10,263.91**	**$9,774.78**
Total Cost (HSaT 5)							**$113,421.24**								
Total Cost (HSaT 2.5)							**$104,401.52**								
Total Cost (no HSaT)							**$95,381.79**								

HSaT 5

Cost per person screened	$12.84
Cost per case detected	$1,090.59

HSaT 2.5

Cost per person screened	$11.82
Cost per case detected	$1,003.86

No HSaT

Cost per person screened	$10.80
Cost per case detected	$917.13

Fixed Coconut Surveillance maintenance cost: $42,328.79

Exchange rate: 1 USD = 1700.99 TSH as of 12/31/14

Appendix 4: 2014 MSaT Activities

Period	District	Shehia	Total Population Examined	Total Positive Cases	Prevalence	HSaT (5)	HSaT (10)	Per Diems	In-Kind Costs	Communication	Fuel	Data	Commodities (incl treatment)	Commodities (excl treatment)
Quarter 2	South	Kibuteni	406	5	1.2	$1,387.65	$2,775.30	$928.88	$553.52	$105.82	$129.34	$235.16	$472.70	$449.19
		Mtende	1060	7	0.7	$1,387.65	$2,775.30	$2,116.44	$954.06	$329.22	$194.01	$291.01	$1,205.67	$1,172.75
	Central	Cheju	1113	16	1.0	$1,387.65	$2,775.30	$2,645.55	$1,351.25	$2,234.02	$761.92	$88.18	$1,306.64	$1,231.39
		Ng'ambwa	531	12	2.3	$1,387.65	$2,775.30	$1,578.51	$716.33	$264.55	$388.01	$279.25	$643.92	$587.48
		Uzi	782	6	0.8	$1,387.65	$2,775.30	$2,281.05	$1,123.33	$399.77	$620.82	$396.83	$893.40	$865.18
	North B	Donge mchangani	1467	26	1.8	$1,387.65	$2,775.30	$2,704.34	$1,416.37	$176.37	$761.92	$734.87	$1,745.33	$1,623.04
		Bumbwini Makoba	527	4	0.8	$1,387.65	$2,775.30	$3,027.68	$1,579.17	$393.89	$1,086.44	$734.87	$601.87	$583.06
	West	Shakani	1659	13	0.8	$1,387.65	$2,775.30	$2,480.94	$1,286.13	$329.22	$776.03	$734.87	$1,896.61	$1,835.47
Quarter 3	Mkoani	Ndagoni	1462	20	1.4	$1,387.65	$2,775.30	$3,248.13	$1,717.55	$393.89	$1,086.44	$734.87	$1,711.58	$1,617.51
Quarter 4	South	Kibigija	966	6	0.6	$1,387.65	$2,775.30	$3,057.08	$1,598.10	$393.89	$905.37	$734.87	$1,096.97	$1,068.75
		Kizimkazi Dimbani	1686	1	0.1	$1,387.65	$2,775.30	$2,292.81	$1,123.33	$258.68	$698.43	$264.55	$1,870.04	$1,865.34
		Muyuni B	227	1	0.4	$1,387.65	$2,775.30	$1,578.51	$716.33	$264.55	$388.01	$291.01	$255.85	$251.15
		Muyuni C	168	1	0.6	$1,387.65	$2,775.30	$1,499.14	$472.12	$264.55	$388.01	$58.79	$190.57	$185.87
	Micheweni	Bule	904	5	0.6	$1,387.65	$2,775.30	$1,578.51	$716.33	$264.55	$323.34	$279.25	$1,023.67	$1,000.16
Total			12,958	123	0.9	$19,427.1	$38,854.20	$31,017.58	$15,323.91	$6,073.01	$8,508.09	$5,858.42	$14,914.84	$14,336.34
Total Cost (HSaT 10)						$162,878.84								
Total Cost (HSaT 5)						$143,451.74								
Total Cost (no HSaT)						$124,024.64								

HSaT 10

Cost per person screened	$12.57
Cost per case detected	$1,324.22

HSaT 5

Cost per person screened	$11.07
Cost per case detected	$1,166.27

No HSaT

Cost per person screened	$9.57
Cost per case detected	$1,008.33

Fixed Coconut Surveillance maintenance cost: $42,328.79

Exchange rate: 1 USD = 1700.99 TSH as of 12/31/14

Appendix 5: DMSO Interview Guide

Part 1: Previous Work Experience

1. Prior to working as a DMSO, what jobs did you hold?
   - How long did you work at that job?
   - What were your responsibilities?
2. Did you have personal experience with malaria, such as yourself or a family member having malaria, prior to working as a DMSO?
3. Why did you decide to work as a DMSO?

Part 2: Training

4. What training did you receive for this work?
   - What training did you receive before starting to work as a DMSO?
   - What training have you received since starting work as a DMSO?
   - How many trainings have you attended?
   - How long did the trainings last?
5. Do you think your training adequately prepared you to work in this position? How so/why not?
6. How could your training have been improved?
   - On what topics would you like additional training?

Part 3: Daily Responsibilities/Workload

7. How many case notifications do you receive per day, on average (high, low seasons)?
   - Are you usually able to collect the information from the health facilities the same day you receive the case notification? If not, how long does it usually take to collect the information from the health facilities? What causes this delay?
8. How many households do you visit per day, on average (high, low seasons)?
   - What are the challenges of visiting households?
   - How many household members do you test at each household, on average?
   - What do you do when you visit a household and not all household members are home?
   - Are any particular household members absent more often than others when you visit, such as fathers, children, etc? If so, who?

- Do you have any suggestions for ways to make sure more household members are home when you visit? Please share.
- How often are you unable to test all household members on your first visit?
- How many times do you have to revisit a household to complete follow up?
- How often are you unable to follow up with all household members?

9. Please describe the steps you take when you arrive at a household for reactive case detection.
    - What are the challenges with completing testing of household members once you arrive?
    - How do you handle these challenges?
10. Once you have arrived at a household, how long does it take to complete your duties, on average?
    - Why might some visits take longer than others to complete?
11. How much of your time is spent traveling to follow up on cases per day, on average?
12. How do you travel to follow up on cases?
    - Why do you travel by this method?
13. When you are not following up on a case, what work do you do?
    - Do your other work duties cause challenges with your DMSO work? How so?
    - Do your DMSO duties cause challenges with your other work? How so?
14. As private health centers are included in the malaria case notification system, do you think the increased caseload will affect your ability to complete follow-ups?
    - Will this be different in the high season?

Part 4: Overall Experience

15. Are you satisfied with your work duties?
16. What could be changed about your work duties to improve your job satisfaction?
17. How could the malaria case notification system be improved?
18. How could the reactive case detection system be improved?
19. Please describe your relationship with the communities you visit. How could this relationship be improved?
    - What kind of community engagement activities do you think would be most useful in improving your relationship with the communities?
20. Is there anything else you would like to say about the program or your role as a DMSO?

Appendix 6: DMSO Interview Codebook

Category	Code	Description
Training	Drug training	DMSO desires additional training on how and when to use particular drugs for malaria treatment
	Tablet training	DMSO desires additional training on tablet maintenance, data entry, and how to better use the tablet
	Testing training	DMSO desires additional training on how to properly test for malaria and new testing technologies
	Geolocation training	DMSO desires additional training on the importance and interpretation of geolocation
	Data analysis training	DMSO desires additional training on data analysis
	Surveillance training	DMSO desires additional training on malaria surveillance
	Mobile phone training	DMSO desires additional training on mobile phone usage
	Community outreach training	DMSO desires additional training on community education and outreach
	Malaria training	DMSO desires additional training on malaria, including how to identify severe malaria
	Mosquito control training	DMSO desires additional training on mosquito control
	Case management training	DMSO desires additional training on case management
	Training duration increased	DMSO thinks initial training duration should be increased before beginning DMSO duties
	Continuing education	DMSO would like additional education opportunities throughout the year
	Job shadowing	DMSO thinks job shadowing should be incorporated into DMSO training

	Certificate opportunity	DMSO would like training to include the opportunity to obtain a certificate
Health facility challenges	Missing info	Health facilities don't capture the required information for follow up in the MCR
	Visit communication	Health facilites should inform malaria positive patients that DMSOs will be visiting their household to test household members for malaria
	Notification delay	Health facilities don't send case notifications in a timely manner
	Staff training	New and existing health facility staff should be trained on malaria case reporting
	HF RDT shortage	RDTs are not always available at health facilities
	Intentional misinformation	People intentionally give false contact information at health facilities
	Close early	Health facilities close early (particularly during Ramadan) making timely case follow up difficult
	Phone lost	Health facility phones are missing
	Phone inoperable	Health facility phones don’t work
	HF airtime	Health facilities run out of airtime
	Private HF case fabrication	Private health facilities may be fabricating malaria cases for profit
Patient follow up challenges	No patient phone	Patients don't have a phone for contact about household follow up
	Household appointments	DMSO wants to schedule household appointments to capture all household members in follow up testing
	School testing	DMSO goes to schools to test children from a target household
	HF testing	DMSO refers missing household members to health facilites for testing
	Severe malaria	DMSO refers patients to health facilities of severe malaria suspected

	Environmental sanitation	DMSO inspects the household and property for mosquito breeding sites
	Remote HH	DMSO must leave motorbike behind to reach household due to access difficulties
	Car	DMSO sometimes uses own car for follow up
	Private HF workload	Including private health facilities will make timely follow up more challenging
	More DMSOs	More DMSOs should be hired to distribute workload
	Refuse testing	Household members refuse to be tested
	HIV testing	Household members think DMSO is testing for HIV
	Run away	Children run away to avoid testing
	HH incentives	Household members could be persuaded to cooperate with incentives (ex: candy for children)
	Neighbor testing	DMSO would like to test neighboring households
	Drug shortage	DMSO sometimes does not have enough drugs to provide treatment, so must refer positive household members to health facilities
	Mainland travel	Travel to mainland causes loss to follow up
	DMSO RDT shortage	DMSO sometimes does not have enough RDTs to complete household testing
	Government distrust	People distrust government services
	Hostility	Some communitites meet DMSOs with hostility
Technology challenges	Network	Inconsistent mobile network delays information relay (change from Airtel to Zantel)

	Broken device	Tablet is broken and should be replaced more regularly
	Rain damage	Tablet is damaged during the rainy season
	Charge	Tablet doesn't stay charged all day
	Motorbike maintenance	Regular motorbike maintenance is needed
	Motorbike discontent	DMSO is not happy with the motorbike (ex: too small, not fast enough)
Supply challenges	DMSO airtime	Not enough mobile airtime to complete duties
	Timely airtime	Airtime is not disbursed in a timely manner
	Fuel shortage	Not enough fuel to complete duties
	Timely fuel	Fuel is not disbursed in a timely manner
	Raincoat	Raincoats should be provided by ZAMEP
	General delays	Consistent delays in equipment and supplies
Community	Malaria education	Community malaria education efforts should be increased (people have heard there's no more malaria)
	Media	Media could be used to distribute malaria education
	Meetings	Community meetings could disseminate correct malaria information
	Work camps	Overcrowding at work camps increases malaria transmission
	Vector control	DMSO would like to be involved in vector control (ex: bednet distribution, IRS)

	Leadership	Communication with community leaders could improve malaria awareness and DMSO relationships with community
Work	Balance	Challenging to balance health facility responsibilities and DMSO work
	Allowance	Allowance should be provided as incentive to work overtime
	Time off	DMSO believes they don't get vacation, weekends, or holidays off work
	Study support	DMSO wants support for additional studying
	Exclusion	DMSO does not feel included by ZAMEP
	Safety	DMSO believes ZAMEP doesn't care for their safety

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