

Performance Evaluation of Zanzibar's Malaria Case Notification (MCN) Surveillance

System: The Assessment of Timeliness and Stakeholder Interaction

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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 in the Graduate School  
of Duke University

2015

ABSTRACT

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## Abstract

Malaria places a tremendous burden on the world's developing countries, with latest estimates making malaria responsible for 198 million cases and 584,000 deaths in 2013. Recent success in malaria control reducing prevalence across the world, however, has placed the goal of malaria elimination at the forefront of countries' malaria strategies. Malaria elimination is the reduction of locally acquired malaria prevalence to zero. Due to the risk each malaria case poses for onward transmission of malaria, quickly detecting and treating all cases of malaria is crucial for malaria elimination. As a result, a robust surveillance system that can track all cases in real-time should be at the core of any malaria elimination program.

One region embarking on malaria elimination is Zanzibar, a semi-autonomous region of Tanzania. Zanzibar has instituted a malaria surveillance system for elimination, termed the Malaria Case Notification (MCN) system in 2012. MCN relies on cell phone reporting to transmit data on all malaria cases detected at health facilities, and tracks all positive cases to their household to test all household members for malaria. As MCN is the core of Zanzibar's public health enterprise for malaria elimination, it should periodically undergo a performance evaluation. Following recommendations in the Centers for Disease Control and Prevention's (CDC's) *Updated Guidelines for Evaluating Public Health Surveillance Systems*, MCN has been evaluated for timeliness (hereafter called response time) a measure of the time-span between surveillance steps, and stakeholder interaction with MCN. As MCN is a surveillance system to support malaria elimination, response time is a critical metric by which to measure its performance. Furthermore, assessing stakeholder interaction provided the analysis of response time a context and identified roadblocks inherent in the surveillance system.

Using case data in MCN from October 2012 to July 2014, provided by RTI and the Zanzibar Malaria Elimination Program (ZAMEP), a time series regression was utilized to measure the association of response time with time. Results indicated that while on average, response time has increased in Zanzibar; it has mixed results at the district level. While the differences in the association of response time with time by the district could be a result of random variation in the data, it can also be explained by differences in the roadblocks stakeholders reported when interacting with MCN. However, due to missing data, a short time span of time-series data, and other limitations of the model, these results may not be robust.

Stakeholder analysis consisted of closed and open ended surveys and focus group discussions with district malaria surveillance officers (DMSOs), a cadre of health workers who are tasked with tracking malaria cases detected at health facilities to their household to test household members for malaria. The most significant issues that were raised by DMSOs were data records at health facilities missing contact and location information of detected malaria cases; reliance on public transport to complete surveillance tasks; misconception that malaria testing at the household was for HIV; and a variety of case prioritization methods used by DMSOs.

These findings indicate that while a surveillance system can automate data collection and reporting through the use of mobile technology, its performance will still rely heavily on health worker performance, community acceptance, and infrastructure within a country. To improve MCN, Zanzibar should proactively communicate to health facilities the importance of record keeping and engage with the community about the importance of malaria testing, among other things. These recommendations can be bolstered with further research on community perceptions on malaria testing. Taken together, these research and operational recommendations can strengthen MCN and strengthen efforts to eliminate malaria in Zanzibar.

## **Dedication**

I dedicate my thesis to my family and friends, without whose support it would not have been possible. I especially want to thank my parents, Suresh and Shobhana Khandekar, and my sister, Meghana Khandekar, who have all been a constant source of encouragement and were always willing to lend an ear.

I also dedicate my thesis to my many friends in the Global Health program, who have all supported me throughout the process.

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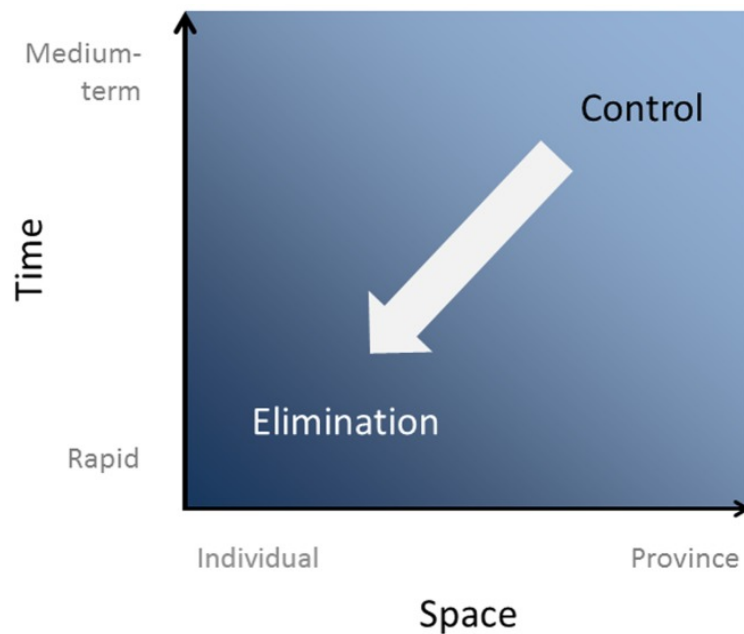
## Introduction

Malaria is one of the most important parasitic diseases infecting humans, currently transmitted in 97 countries (WHO 2014). While once prevalent throughout the majority of the populated world, global control efforts have eliminated malaria from the developed world. However, relaxation of these efforts in 1970s and 1980s enabled malaria prevalence to resurge. In response to this rise, governments across the world looked to the historic Global Malaria Eradication Program of the 1950s for its institutional knowledge to guide control programs. World-wide efforts, supported by the Global Malaria Control Strategy and Roll Back Malaria, were able to reduce malaria incidence by 30% between 2000 and 2013 (WHO 2014). These successful efforts have raised interest in malaria elimination, a goal abandoned with the disassembling of the Global Malaria Eradication Program in 1977.

Thirty-two governments of the world have made formal declarations to pursue malaria elimination (Feachem, Phillips et al. 2010). The government of Zanzibar, a semi-autonomous region of Tanzania, is one such government. Making its formal declaration in 2012, Zanzibar aims to eliminate malaria by 2018 and has established a government program dedicated to support these goals, the Zanzibar Malaria Elimination Program (ZAMEP) (ZAMEP 2012). Zanzibar has had a storied history with malaria control. Interventions were introduced and scaled back twice in the 20<sup>th</sup> century, with prevalence falling and rising dramatically, respectively. Interventions were once again introduced in the mid-2000s, with the majority of financial assistance from the Global Fund to Fight Aids, Malaria, and Tuberculosis (Global Fund) and commodity donations from the U.S. President's Malaria Initiative (PMI). A rapid scale up of interventions has dramatically reduced malaria prevalence from more than 70% to less than 1% in 2012 (TACAIDS 2012).

This marked reduction brought the government of Zanzibar to a crossroads. With the two options of continuing with sustained control or elimination, Zanzibar conducted an elimination

feasibility assessment, the first of its kind in the world (ZMCP 2009, Moonen, Cohen et al. 2010b). Its findings indicated that elimination was possible but had to be supported by stringent interventions, one of which was determined to be a robust surveillance system. Surveillance for malaria elimination has been discussed extensively in the literature, with emphasis being placed on rapid real time information production of all malaria cases. The figure below emphasizes the transition towards localized and speedy case detection necessary in public health surveillance for malaria elimination.



**Figure 1: Targetted surveillance and response in the shift towards elimination**  
**Source: (Ohrt, Roberts et al. 2014)**

Zanzibar created such a surveillance system in 2012, called the Malaria Case Notification (MCN). MCN enables daily reporting of all cases detected at public health facilities, follow-up of malaria cases, testing and treatment of household members, and provision of preventative interventions and health information. Such rapid reporting and response are possible through MCNs novel use of text-based reporting and a mobile app called Coconut Surveillance, with public health

facilities reporting cases via text messages and specialized District Malaria Surveillance Officers (DMSOs) using Coconut Surveillance to follow-up on cases (RTI 2013c, Ohrt, Roberts et al. 2014).

Zanzibar's MCN surveillance system is a core program of ZAMEP's public health enterprise for malaria elimination. To ensure that Zanzibar's elimination goals can be met by 2018, ZAMEP must conduct a performance evaluation on MCN's. Evaluation of surveillance systems is an essential component of public health practice and can "determine whether the system is meeting its objectives, serving a useful public health function, and operating as efficiently as possible (Romaguera 2000, p. 176)." The World Health Organization (WHO) and the Center for Disease Control and Prevention (CDC) have both issued guidelines on surveillance evaluation to address this need. Both of these sets of guidelines emphasize investigation of surveillance system attributes, information gathered on the notifiable diseases(s), quality, timeliness, completeness and perceived usefulness of information gathered (CDC 2001, WHO 2006). The guidelines stress that all evaluation activities must be pursued with the purpose of producing findings that can enhance surveillance efforts in addition to disease control and elimination efforts. This study will draw on the principles highlighted in these guidelines to evaluate Zanzibar's MCN surveillance system. MCN is a surveillance system meant to support malaria elimination and should be capturing cases rapidly. As such, timeliness will be a critical metric of this performance evaluation.

**Specific Aims of This Thesis:**

1. Evaluation of MCN's Timeliness: Surveillance systems for malaria elimination must emphasize rapid case detection, and Zanzibar's MCN surveillance system is no different. The main purpose of this study is to evaluate the principle of "timeliness," described in the CDC and WHO guidelines as the time within which surveillance steps take place. Determining the timeliness of MCN will be crucial to understanding if it is detecting and

following up on cases in a time frame that supports Zanzibar's goal of malaria elimination.

Specifically, the evaluation of timeliness will seek to answer the following questions:

- a. Has timeliness improved since MCN inception in 2012?
  - b. Is workload associated with timeliness?
  - c. Does the association of timeliness with time and workload vary by district?
2. Assessing stakeholder interaction with MCN: The two groups of stakeholders discussed above, health facilities and DMSOs, are both crucial to MCN. However, DMSOs arguably have a more strategic role, as they alone follow-up on cases to the household level, test household members, and collect additional information on the penetration of malaria interventions. As a result, they are positioned to provide key insight on roadblocks that MCN confronts. This study will investigate DMSO interaction with MCN at three stages:
- a. Health Facility Level
  - b. Travel to Households
  - c. Household investigation and household member testing

This evaluation will contribute findings that will be used to strengthen MCN and aid Zanzibar in its goal of malaria elimination. While these findings will be geared to address the specific challenges that Zanzibar faces, they will also likely touch on crosscutting issues that all malaria eliminating countries experience.

The remainder of this thesis will be organized as follows: Chapter 1 will provide an in-depth background on malaria epidemiology, historical control efforts, and current global elimination efforts; Chapter 2 will focus on the history and development of public health surveillance as a practice and a concept as well as surveillance for malaria control and elimination; Chapter 3 will provide a case study on Zanzibar, its history with malaria control, and its current elimination efforts; Chapter 4 will present a description of Zanzibar's MCN surveillance system; Chapter 5 will present a

overview on evidence based public health, the role of surveillance systems in providing an evidence case, the value of evaluating public health system components, and a literature review on public health surveillance evaluation; Chapter 6 will present the methods of this current study; Chapter 7 will present the findings; and Chapter 8 will present the Discussion, Recommendations, and Conclusion.

# 1. Malaria Epidemiology, Control, and Elimination Efforts

## 1.1 Epidemiology & Transmission

Malaria is one of the most important parasitic diseases infecting humans and is currently the fourth largest cause of death and disease in low-income countries (WHO 2014) with 3.2 billion people in 97 countries being at risk of contracting malaria. Latest estimates indicate that malaria is responsible for 198 million cases and 584,000 deaths in 2013 (WHO 2014). Malaria's burden of disease is the highest in the WHO African Region, where an estimated 90% of all malaria deaths occur. Additionally, malaria places its burden disproportionately on the most vulnerable and poorest communities. Not only does it primarily impact low and middle-income countries, it affects the poorest amongst endemic countries (WHO 2014).

A protozoan disease, malaria in humans is transmitted by five species of parasites: *Plasmodium falciparum*, *P. vivax*, *P. ovale*, *P. malariae*, and *P. knowlesi*. Most malaria cases are caused by either *P. falciparum* or *P. vivax* and are transmitted by the *Anopheles* mosquitos, which only bite during the nighttime. *P. falciparum* has the highest pathogenicity, with a case fatality rate amongst those not immune up to 30% if no treatment is provided (Snow and Gilles 2002) and predominates in Africa (WHO 2013). Though *P. vivax* has a lower fatality, it has a wider geographic distribution than *P. falciparum* due to its ability to develop in the *Anopheles* mosquito at higher altitudes and lower temperatures (WHO 2013). While the remaining species have relatively low case fatality rates, they can cause fatal complications (Wernsdorfer 2012).

The main determinants of malaria transmission are intensity of malaria and density, longevity, biting habits, and efficiency of the mosquito vector (Wernsdorfer 2012). Transmission intensities are the highest in sub-Saharan Africa, where *P. falciparum* dominates. In such settings, morbidity and mortality are the most pronounced during childhood (Sinka, Bangs et al. 2012). Constant year-round infections are termed as stable transmission. Conversely in areas where

transmission is low, erratic, or focal, it is termed unstable transmission. In the latter, full protective immunity from malaria is not acquired and symptomatic disease can occur at all ages. This places populations at risk of epidemics if changes in environmental or socioeconomic conditions, in conjunction to breakdown of malaria control, occur (White, Pukrittayakamee et al. 2014).

Transmission of malaria was quantified with the work of Sir Ronald Ross laying the foundations for quantitative analysis. A key metric with which transmission is measured is the basic reproductive rate ( $R_0$ ), which is the number of cases distributed by one case under conditions of very low endemicity, full susceptibility to infection, and no control measures. If  $R_0$  is greater than 1, then the number of infected people increases, whereas if  $R_0$  is less than 1, the number declines. The  $R_0$  of malaria transmission is calculated using the following formula:

$$R_0 = \frac{ma^2 bp^n}{-r \ln p}$$

**Equation 1: The Basic Reproductive Rate**  
**Source: (Wernsdorfer 2012)**

The equations elements are the following (Gething, Patil et al. 2011, Wernsdorfer 2012):

m= density of female vector anopheles in relation to man

a= number of humans bitten by one mosquito per day

b = the proportion of anopheles mosquitos with sporozites in their salivary glands

p = the probability of the mosquito vector to survive through 1 day

n = the number of days required for complete sporogeny

r = daily recovery rate of the infected human parasite donor (based on an assumption of 80 days of infectivity in the course of infection with *P. falciparum*.)

The basic reproductive rate essentially provides an index of transmission intensity and is an important metric by which priorities and expectations for control can be set against (Smith, McKenzie et al. 2007). For example, at low  $R_0$  levels, elimination may be feasible but at high  $R_0$  levels control measures may require heavy investments. A recent study on 121 African populations estimated that  $R_0$  ranges from close to 1 to over 3,000 (Smith, McKenzie et al. 2007).

The  $R_0$  may not always be the best metric for measuring malaria transmission in a country. In places that malaria is under control or has been eliminated, there is a degree of outbreak control, so a more appropriate measure is the reproductive number under control,  $R_C$ . While the  $R_0$  provides information on how many additional cases of malaria would arise from the introduction of a single malaria case in an area with no control measures, the  $R_C$  provides the expected number of new cases to arise after the introduction of a single case in an area with control measures in place (Cohen, Moonen et al. 2010).

## ***1.2 Control Measures and Diagnostics***

Numerous interventions exist for malaria control and treatment. The predominant strategy to prevent malaria is through vector control. The two major strategies within vector control efforts are deployment of bed nets (LLINs) and indoor residual spraying (IRS). Deployment of pyrethroid-insecticide treated mosquito nets has reduced all-cause mortality by roughly 20% within children less than 5 years of age (Phillips-Howard, Nahlen et al. 2003). Furthermore, use of bed nets has positive externalities outside of protecting the user by killing the anopheline mosquitos, termed the mass effect (Moonen, Cohen et al. 2010a). IRS makes use of insecticides to coat walls and ceilings and can kill mosquitos within 12 hours of contact. While LLINs have been found to more useful in medium to high transmission settings, IRS has been found to be useful in low-medium transmission settings (Fullman, Burstein et al. 2013). The use of these two vector control strategies has been growing and together, LLINs and IRS account for up to 60% of global malaria investments (RBM 2008).

The current gold standard for malaria diagnosis is the use of Giemsa-stained thick blood film microscopy, as it provides information on parasite species and density. The detection threshold has been calculated to be 4-20 parasites/uL; however under field conditions a threshold of 50-100 parasites/uL is more realistic (Payne 1988). While PCR provides more accurate diagnosis, it is expensive and impractical to use in primary health clinics in developing countries. However, even microscopy can be out of reach for many health clinics, as the approach requires trained personnel to prepare and read the slides as well as rigorous quality control. As a result, the use of rapid diagnostic tests (RDTs) has gained attraction. RDTs use a small amount of blood to detect malaria antigens and display their result as a colored line, making it both easy to administer and read (Wongsrichanalai, Barcus et al. 2007). To be useful, however, RDTs need to have a sensitivity of 95% (WHO 2000). While RDTs have achieved this high sensitivity for *P. falciparum*, they have not for non-*P. falciparum* species. Furthermore, the sensitivity of RDTs, regardless of the parasitic species, decreases as the parasitic density reduces (Forney, Magill et al. 2001).

### **1.3 Historical Eradication and Control Efforts**

#### **1.3.1 Global Malaria Eradication Program (GMEP) Era (1955-1970s) & Malaria Resurgence (1970s-1980s).**

Malaria elimination and control efforts date back to the 19<sup>th</sup> century, starting with the discovery of the plasmodium parasite and its transmission by anopheles mosquitos. Little progress was made until the mid-1900s due to the World Wars disrupting control efforts (Wernsdorfer, Hay et al. 2009). However in 1955, the WHO formed the Global Malaria Eradication Program (GMEP). GMEP had an ambitious global to interrupt malaria transmission in all endemic areas, with the

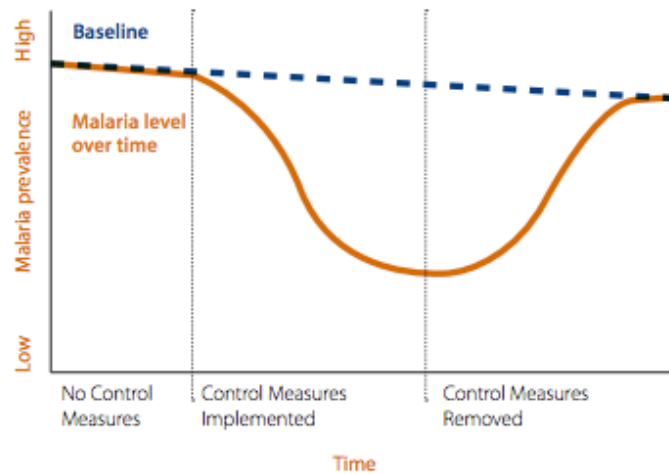
exception of sub-Saharan Africa<sup>1</sup>, and relied on vector control and systematic detection of malaria cases. At the height of its efforts in 1969 GMEP covered 1.4 billion people under its umbrella of activities (Najera 2001) and as of 1978, 37 of the 143 malaria endemic countries were classified as malaria free (Wernsdorfer 1980, RBM 2011b). Success of GMEP, however, was mixed throughout its lifespan. For example, findings of resistance to first line IRS and treatment options lead to waning public support for GMEP in the 1960's. Concern for programmatic feasibility peaked in 1966 during the 19<sup>th</sup> World Health Assembly (WHA) and by 1969, it was clear that eradication targets would not be reached. GMEP faced financial constraints in the late 1960s, as U.S. commitments, which represented 85% of all GMEP funds, were curtailed in 1963 (Najera 2001). Support for GMEP was officially withdrawn in 1969 at the 22<sup>nd</sup> WHA, where it was determined that eradication was no longer feasible and that control of malaria with current available means should be encouraged. Furthermore, dwindling global support for eradication became critically damaged by the 1973 global oil crisis which caused significant increases in the prices of insecticides (Najera, Gonzalez-Silva et al. 2011, RBM 2011b).

Despite these setbacks, the institutional knowledge developed through these efforts was maintained, as countries that had eliminated malaria remained malaria-free (Najera 1989). On the other hand, malarious nations faced insufficient guidance and funding. This programmatic weakening, in addition to complacency due to malaria case reductions, led to a worldwide resurgence of malaria during the 1970s and 1980s. A systematic review on historical resurgence events, determined that resurgence in Latin America was associated with relaxation of IRS programs, whereas resurgence in Asia, Eastern Europe, and Africa followed relaxation of overall control programs (Cohen, Smith et al. 2012).

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<sup>1</sup>The sub-Saharan region of Africa was temporarily excluded from GMEP's campaign as the WHO African Regional Committee deemed transmission intensity to be too high preparations and control interventions to be infeasible (WHO 1956)

Resurgence of malaria allows malaria incidence to rise to baseline levels. These levels are determined by factors such as climate and mosquito vectors, highlighting the importance of malaria programs to focus on potential for malaria not just on the burden (E2Pi 2011). As mentioned in the previous section, the potential for malaria is captured by the  $R_0$  factor. Figure 2 depicts this natural occurrence and can be seen below.



**Figure 2: Control Measure Removal and Resurgence to Baseline Prevalence**  
**Source: (E2Pi 2011)**

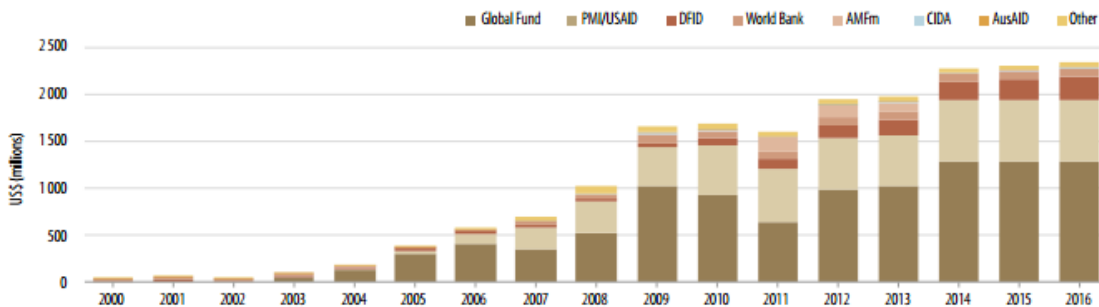
### **1.3.2 Post-1990s Global Malaria Partnership Era (1990s – Present)**

The resurgence of malaria burden created an impetus within the WHO to reassess its position on malaria and in 1992 it adopted its seminal *Global Malaria Strategy* at the Amsterdam Ministerial Conference on Malaria, which emphasized control as the desired strategy to contain malaria (RBM 2011a). Very few resources were targeted for malaria, however, throughout the 1990s. It was not until the late 1990s to mid 2000’s that global efforts for malaria control truly emerged. Arguably it was the launch of Roll Back Malaria (RBM) in 1998 that ushered in a renewed interest in malaria, a movement that was solidified in 2000 by the adoption of the *United Nations Millennium Declaration* and its Millennium Development Goal (MDG) targets. The subsequent years witnessed

heightened activity in programmatic support for malaria control, including the launch of the *Global Fund to Fight Aids, Tuberculosis, and Malaria (Global Fund)* in 2002; and the *U.S. President's Malaria Initiative* in 2005. A timeline of key events in malaria control efforts can be seen in Appendix 1.

These efforts established global targets for malaria, the most important being MDG 6c in 2000, WHA in 2005, and the 2008 RBM Global Malaria Action Plan (GMAP) targets. MDG 6c calls for nations to “halt by 2015 and begin to reverse the incidence of malaria and other major diseases (UN 2000)”, and the WHA and RBM GMAP targets call for the 75% reduction of malaria cases by 2015 and the reduction of malaria deaths to near zero by 2015 (WHO 2014). Attaining these targets for control and elimination have been estimated to require an investment of \$5.1B per year.

Financing for malaria control grew dramatically since the launch of these partnerships. In fact, international disbursements to malaria endemic countries increased from under \$100M in 2000 (WHO 2013) to \$2.18B in 2013. Despite these remarkable gains, there is still a funding gap of \$2.4B (WHO 2014). Financing trends since 2000 and their projections to 2016 can be seen below in Figure 3. The growth in funding has been largest in the WHO African Region, as has total funding for malaria (WHO 2014). Priority of funding has not only gone to specific regions, but also to countries that are on track to achieve the 75% decrease in malaria incidence target in addition to those in the pre-elimination and elimination phase (WHO 2013). (Details on the differences between control, pre-elimination, and elimination will be discussed below in the section on the current global strategy).



**Figure 3: Malaria Financing Trends (2000-2013) & Projections to 2016**  
**Source: (WHO 2013)**

The influx of financing and programmatic support that emerged since 2000 has been associated with remarkable gains in malaria control and elimination. Donor financing funded a massive scale up of control tools, a process that RBM has termed “scaling up for impact”, and has successfully shifted numerous countries towards the goal of malaria elimination. A list of different countries and their stages of malaria elimination can be seen in Figure 5 in the section below. Furthermore, the success of the new era of malaria partnerships is also captured in the reduction of malaria incidence and mortality globally. Between 2000 and 2013, malaria cases fell from 227 million to 198 million globally, with a 34% reduction in the WHO African Region. During the same time period, malaria related mortality rates, taking into account population growth, have declined by 47% globally and 54% in the WHO African Region (WHO 2014).

### 1.3.3 Current Global Malaria Strategy

There has been unprecedented progress in malaria control in recent years, largely due to the success of commitment of endemic countries and financial and programmatic support of malaria partnerships. These impressive gains have been driven by four instrumental global agencies: the WHO, United Nations Development Program (UNDP), and RBM Partnership, and the Global Fund. The former three, as mentioned above lent to the 2015 targets. However, it was the RBM 2008

GMAP that formally set the expansive malaria control and elimination strategy that countries operate under today.

The 2008 GMAP's global strategy consists of three components: control elimination, and research. This agenda has been supported and expanded upon by civil society and academia, such as the Malaria Elimination Group (MEG), which have collectively promulgated the concept of "shrinking the malaria map" (Feachem and Sabot 2008, RBM 2008, Feachem and MEG 2009, Alonso, Brown et al. 2011). These three strategic components are described below:

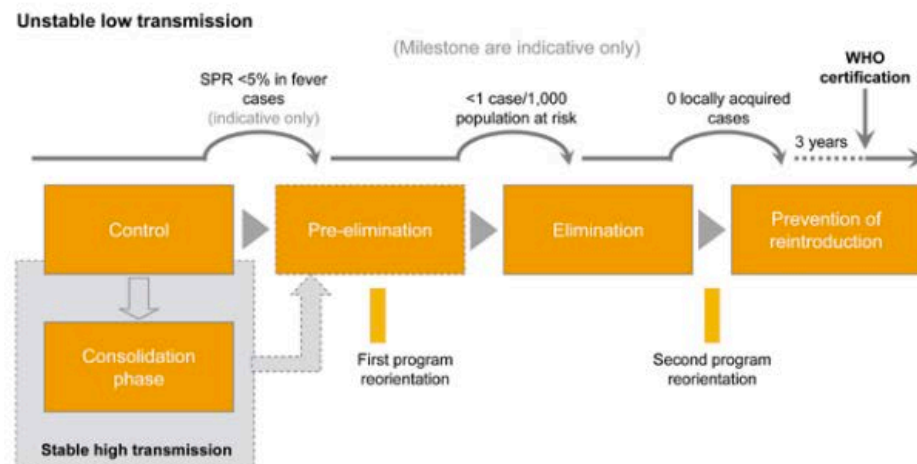
Control: Malaria control is the reduction of malaria "morbidity and mortality to a locally acceptable level through deliberate efforts using (RBM 2008, p. 47)" the tools available. Control consists of two processes: scaling up interventions and sustaining control measures over time.

- Scaling up for Impact: This stage has the goal of reaching coverage for all populations at risk rapidly. Scaling up both preventative and curative interventions, a process that RBM has called scaling up for impacting (SUFI), can have a dramatic impact on malaria burden.
- Sustained Control: Even after reductions in malaria incidence, countries need to maintain levels of coverage, as history has shown the consequences of resurgence if control efforts are relaxed. This stage has the goal of maintaining coverage for all populations at risk until it is deemed appropriate to relax control program components or malaria has been eliminated.

During this stage, maintaining political, financial, and technical support is critical.

Elimination: The WHO officially defines elimination as the reduction "to zero the incidence of locally acquired malaria infection in a specific geographic area as a result of deliberate efforts (RBM 2008, p.74)." Once achieving this target, continued measures are often necessary to prevent re-establishment of transmission. The RBM partnerships endorses elimination but only in countries that

have a low malaria burden, are located near natural borders of malaria<sup>2</sup>, have strong commitment to elimination, and have the health system capacity to manage an elimination program. After three years in a state of elimination, a country can receive a malaria-free certification from the WHO. Key epidemiological milestones recommended by the WHO on the road to elimination include a slide positivity rate of less than 5% in patients with a fever (febrile) to achieve pre-elimination standing and an incidence rate of less than 1/1000 to be considered in the elimination stage (RBM 2008). This process is depicted below in Figure 4.



**Figure 4: Pathway to Malaria Elimination**  
**Source: (WHO 2007)**

<sup>2</sup> **Malarious Borders:** This criterion for malaria elimination rests upon the country’s location relative to the endemic border of malaria, which relies on latitude, altitude, and climate. Edges of the endemic regions have lower vulnerability to the reintroduction of malaria. As these areas gradually reduce the incidence of malaria, it becomes easier for countries within endemic regions to do the same (Feachem 2008). This gradual process of reducing the burden of malaria towards the endemic heartland is called “shrinking the malaria map.”

Research: In addition to control and elimination efforts, long-term goals require new tools, policies, and intervention delivery mechanisms. This can only be achieved through targeted research efforts on three fronts:

- **Intervention R&D:** As malaria control and elimination are pursued across the world, the necessity of effective anti-malarial intervention grows. Malaria is not the only public health problem countries face, so emphasis must be placed on increasing intervention's ease of use, delay emergence of resistance, and reducing cost of producing interventions (RBM 2008). For countries embarking on elimination, research efforts must be focused on proper targeting of asymptomatic cases.
- **Policy Research:** Such research can inform interventions and programs best suited for the country or regional context.
- **Operational and Implementation Research:** Understanding the effectiveness of interventions and programs is crucial to continued and sustained gains in malaria control and elimination. Findings from research efforts can improve the delivery, quality, equity, and effectiveness of malaria interventions.

With 2015 having been reached, the global community is turning to a new malaria agenda for the post-MDG world. The effort is being led by the WHO's Malaria Policy Advisory Committee (MPAC) and the RBM Partnership. The former is launching its Global Technical Strategy for Malaria Control and Elimination and the latter is launching a new Global Malaria Action Plan, GMAP2, which is currently undergoing a consultative process. Both are scheduled to be launched in the second half of 2015 (Abdulla, Alonso et al. 2013).

### 1.3.3.1 Renewed Interest in Malaria Elimination: Towards “Shrinking the Malaria Map”

While elimination during the Global Eradication Program era suffered setbacks, the gradual scale up of control programs in the last decade has made malaria elimination more epidemiologically feasible, especially in areas of unstable transmission (RBM 2008). Countries across the world have taken advantage of this reality to pursue malaria elimination. The number of malaria elimination countries is contested, with the MEG acknowledging 34 countries and the WHO acknowledging 26. It is unclear, however, what epidemiological definition the MEG used when constructing its list. As the WHO provides the most recent categorization, their list of 26 countries in the pre-elimination, elimination, and prevention of reintroduction stage has been presented in Figure 5 below, in addition to all WHO malaria free certified countries. According to their definition for pre-elimination and elimination, countries need to be in the process of updating their national malaria policies or already have their national policies updated to meet the programmatic needs of elimination.

Region	Pre-elimination	Elimination	Prevention of reintroduction	Certified as malaria free since 2000
AFR	Cabo Verde	Algeria		
AMR	Belize Costa Rica Ecuador	El Salvador Mexico Paraguay	Argentina	
EMR		Iran (Islamic Republic of) Saudi Arabia	Egypt Iraq Oman Syrian Arab Republic*	Morocco – 2010 United Arab Emirates – 2007
EUR		Azerbaijan Tajikistan Turkey	Georgia Kyrgyzstan Uzbekistan	Turkmenistan – 2010 Armenia – 2011
SEAR	Bhutan Democratic People’s Republic of Korea	Sri Lanka		
WPR	Malaysia	Republic of Korea		

**Figure 5: Country classification by elimination stage**  
**Source: (WHO 2014)**

However, national efforts to pursue elimination may not be enough. Imported cases from neighboring countries can hamper national efforts. As a result, it is important for malaria elimination to be treated as regional public good, with regional collaborations and targets being used to mitigate

cross-border challenges. Such regional political commitment has been made towards elimination and can be seen in the multi-country elimination efforts such as the Asia Pacific Elimination Network (APMEN)<sup>3</sup>, the Elimination Eight (E8) Regional Initiative<sup>4</sup> in southern Africa, the Tashkent Declaration<sup>5</sup>, and the Saudi-Yemeni Partnership in Combating Malaria<sup>6</sup> (MEG 2013).

As countries transition from control to elimination, their programs need to be re-oriented to meet the needs. This is most crucial at both the pre-elimination stage and before the prevention of reintroduction stage

Within these reorientations, several program components need to be strengthened and developed, and emphasis must be placed on stronger data collection and a “relentless focus on surveillance and response (Feachem, Phillips et al. 2010, p.1572).” Overall, there has been a consensus that the following program components are essential for an elimination program (RBM 2008, Sabot, Tulloch et al. 2009):

- Surveillance: This component has been characterized as the cornerstone of any elimination program. A program must have the capability to detect, investigate, and respond to every individual case to achieve and sustain zero transmission.
- Vector Control in Active Foci: Interventions, such as bed nets and IRS, must be targeted specifically to active foci, areas with high transmission or high susceptibility to transmission.

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<sup>3</sup> APMEN was established in 2009 to bring attention to malaria elimination in the Asia Pacific. APMEN is composed of 12 countries that are pursuing malaria elimination.

<sup>4</sup> E8 was launched in 2009 and is an eight-country effort to achieve elimination in the four southern most countries in Africa, Namibia, Botswana, Swaziland, and South Africa. The E8 effort highlights the importance of cross-border collaborations to “shrink the malaria map” as elimination in the aforementioned countries will only be possible if their northern neighbors tighten control efforts.

<sup>5</sup> The Tashkent Declaration was established in 2005 and was formed by 9 countries in the WHO European region. These nine countries are primarily located in the Caucasus region in Eurasia.

<sup>6</sup> The Saudi-Yemeni Partnership was launched in 2001 with goal of eliminating malaria in the peninsula by 2020, with Saudi Arabia providing the majority of financial and technical support to Yemen.

- **Case Detection and Management:** All malaria cases must be detected using appropriate diagnostic tools, such as microscopy and RDTs, with robust quality assurance. Treatment must also be available for all detected cases.
- **National Programs:** Countries embarking on elimination must have strong central capacity to guide progress towards elimination goals and engage in ongoing monitoring of the elimination programs against their objectives.
- **Public and Private Sector optimization:** Formal private facilities should be fully integrated into the elimination program and surveillance system. This will ensure that all cases are identified and responded to.
- **Advocacy, Information Education Campaigns, and Behavioral Change Communication to combat fatigue:** Malaria programs suffer from an “out of sight, out of mind” paradox (E2Pi 2011). Political fatigue towards malaria elimination has been well documented, as well as its repercussions. Accordingly, maintaining political and financial support is crucial especially when malaria no longer poses a public health burden, as often happens during elimination. This calls for communication and education to the general population to understand ongoing risk of malaria in addition to continuous re-training of health workers.
- **Cross-border Initiatives:** Achieving elimination and prevention of re-introduction requires countries to prevent imported cases of malaria and engage in cross-border collaboration with neighboring countries. The latter is particularly critical with population movement.

As a result, political will is not the only requirement for a country to proceed towards malaria elimination. Operational, technical, and financial commitments to malaria elimination are critical requirements as well (Feachem, Phillips et al. 2010). Zanzibar, a semi-autonomous region of Tanzania, was the first country to conduct such an assessment (ZMCP 2009, Moonen, Cohen et al. 2010b).

## **1.4 Summary**

Malaria is one of the most important parasitic diseases currently affecting humans. Not only is it the fourth largest cause of mortality and morbidity in low-income countries (WHO 2014) it also disproportionately affects the poorest communities. To combat malaria, numerous interventions have been developed, including bed-nets and IRS. Furthermore, diagnostic methods such as microscopy and RDTs have been deployed in the field. These malaria control efforts date back to the 19<sup>th</sup> century, with the first global effort being the Global Malaria Eradication Program. Mixed success of the GMEP led to its abandonment in 1969. Scaling back of malaria control efforts resulted in resurgence events worldwide in the 1970s & 1980. However, malaria control never returned to the global forum until the late 1990s. The launch of global partnerships and agenda setting followed the formation of RBM in 1998. With RBM's 2008 GMAP setting the global strategy and international organizations such as PMI and the Global Fund providing financial and commodity support, control efforts were able to accomplish significant gains. The current global strategy for malaria control consists of three separate goals: 1) malaria control, 2) elimination, and 3) research. Reductions in burden of malaria in the last decade have made malaria elimination a practical goal, with academia and formal strategic documents identifying a cornerstone of elimination efforts as public health surveillance.

For the purpose of this thesis, surveillance efforts have been focused on as most vital for malaria elimination efforts. The next chapter will discuss the development of public health surveillance as a concept and a practice in addition to discussing the key issues relevant for surveillance efforts for malaria.

## **2.0 Public Health Surveillance & Surveillance for Malaria**

Public health surveillance is an essential public health function. As an information provision arm of public health, surveillance enables that effective action is taken for responding to, controlling, and preventing diseases.

### **2.1 History and Purpose of Surveillance**

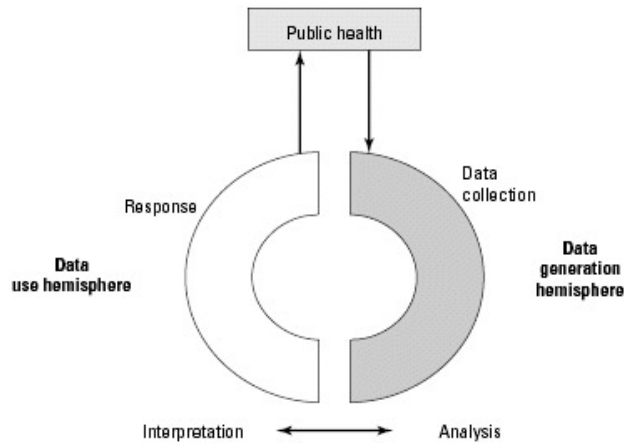
Surveillance dates back to the 14<sup>th</sup> century, with its first recorded use in the Republic of Venice. During the bubonic plague of 1348, 3 guardians of public health were appointed to identify ships carrying infected people and prevent them from disembarking (Moro and McCormick 1988, Declich and Carter 1994). The concept of surveillance has evolved since then but has always focused on detecting individual cases and taking action regarding infected individuals. This *case surveillance* has been supported by *statistical surveillance*, a body of surveillance that focuses on population health. The latter began with John Graunt's analysis of England's Bills of Mortality in 1662 (Choi 2012) and was formalized by William Farr and Lemuel Shattuck in 1838 and 1850, respectively, when they analyzed mortality data in England and sanitary conditions in Massachusetts (Langmuir 1976, Eylenbosh and Noah 1988, Stroup and Berkelman 1998). Farr's and Shattuck's works collectively created an impetus through which the collection of vital statistics and health data became a routine public health activity.

As the practice of surveillance has evolved, so has its concept. Before 1963, surveillance was associated with monitoring those who were at risk for developing contagious infectious diseases. It was not until Alexander Langmuir defined the term as "the continued watchfulness over the distribution and trends of incidence through the systematic collection, consolidation, and evaluation of morbidity and mortality reports and other relevant data (Langmuir 1963, p.182-183)" that surveillance's focus expanded to the occurrence of diseases in populations (Stroup and Berkelman 1998). At the time, however, Langmuir limited the purview of surveillance to the collection, analysis, and dissemination of data and excluded control activities from his definition. While surveillance does

not include public health action enacted from the interpretation of surveillance data, others have stressed the essential link between the two. One of the most vocal proponents of this link was a former CDC director, William Foege who stated “the reason for collecting, analyzing, and disseminating information on a disease is to control that disease. Collection and analysis should not be allowed to consume resources if action does not follow (Foege, Hogan et al. 1976, p. 30).” This link between surveillance and public health practice that Foege stressed was reiterated by the CDC in 1986 (Choi 2012) and is likely what initiated the transition from describing surveillance activities as *epidemiological surveillance* to *public health surveillance*. Introduced by Thacker and Berkelman in 1998 the term *public health surveillance* captured the link between surveillance and action, whereas epidemiological surveillance was more closely associated with epidemiological research. The CDC and the WHO have since captured public health surveillance as a term and emphasize public health action (CDC 2001, Choi 2012).

Public health surveillance is now perceived as an essential function of a public health system, having the ability to use its information to “improve[s] the efficiency and effectiveness of health services by targeting interventions and documenting their effect on the population (Nsubuga, White et al. 2006, p. 1000).” This integral connection is captured in diagram below in Figure 7. Implicit in the connection between public health surveillance and public health practice is the formers ability to enable evidence-based decision-making.

As such, there are three broad objectives of a surveillance system. The first one is the description of public health disease and link to public health action. It is only after quantifying trends in disease that public health action, such as disease investigation, can take place. This trend analysis and follow-up investigations is the main purpose of a surveillance system.



**Figure 6: Linking Public Health Surveillance to Public Health Action**  
**Source: (Nsubuga, White et al. 2006)**

The second objective of a surveillance system is to understand the epidemiology of a disease. Through assessing incidence and prevalence, as well as risk factors associated, a surveillance system can provide public health officials with the knowledge necessary for establishing control measures. The last objective of a surveillance system is the establishment of a baseline. These data are essential to benchmark the effectiveness of an intervention or control measure against.

## ***2.2 Data Collection and Types of Surveillance***

At the heart of surveillance systems is the data collection procedure. Quality of a surveillance system is only as good the data collected, and it can be determined by the motivation of public health workers, ease of data collection, and completeness and timeliness of case detection (CDC 2001, CDC 2011). While the motivation and ease of data collection are universally important for surveillance systems, the importance of timeliness and completeness of case ascertainment and reporting can vary

according to the disease under surveillance. Though the importance of completeness<sup>1</sup> and timeliness may vary by the disease under surveillance, they are both critical metrics of a surveillance system.

Timeliness is especially important as it captures the length of time a surveillance system takes to collect, analyze, and disseminate data. Specifically, timeliness measures the time within which surveillance steps are taken. It depends on not only what condition is under surveillance but also on how data are collected. Benchmarks of timeliness will also depend on the condition in addition to how data will be used. For example, acute infectious diseases will require rapid timeliness, whereas chronic conditions may not.

Surveillance is not a one-size-fits-all glove and certain attributes need to be emphasized given the severity and incidence of the disease being tracked. The procedures used currently by a majority of surveillance systems are (Nsubuga, White et al. 2006):

- **Passive Surveillance:** Data recipients must wait for cases to present themselves at health facilities before cases are reported to a public health agency. While passive surveillance is relatively inexpensive, it can provide critical information. However, the quality of data obtained at health facilities is difficult to control.
- **Active Surveillance:** In this type of data collection procedure, cases are searched for. Active surveillance aids in circumstances where some cases may be missed by passive surveillance. While active surveillance is costly to use, it provides the most accurate and timely information (Nsubuga, White et al. 2006).

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<sup>1</sup> **Completeness:** Another metric of a surveillance system, this is the proportion of diagnosed health events that are reported to a public health agency. For the purpose of monitoring trends, completeness need not be 100% if reporting is representative of the population. However, for infrequent diseases and diseases that require immediate public health action, completeness is more important.

- **Sentinel Surveillance:** This method of public health surveillance relies on a pre-arranged sample of reporting sources to more accurately represent severity of a disease. Where such a system loses completeness, it gains in reliability, timeliness, and cost (CDC 2006)
- **Syndromic Surveillance:** This form of public health surveillance can be active or passive, but its hallmark is that it relies on clinical features rather than laboratory confirmed cases. As these surveillance systems are inexpensive and provide timely information, they are often the first to be initiated in developing countries. Developed countries, however, use these surveillance systems for biological terrorism.
- **Surveillance based on Secondary Data:** Data sets are made available by health agencies and allow for high quality data analysis. However, these data sets can often be compiled, cleaned, and packaged months to years after initial data collection. As a result, using secondary data sets are more beneficial for evaluating the effectiveness of long-term interventions rather than for enabling real time action (CDC 2006)

The specific sources of data and methods used depend on the disease under surveillance. This reflects the reality of disease itself and will promote the flexibility of surveillance systems to alter procedures as needed.

## ***2.3 Malaria Surveillance***

A malaria surveillance system consists of tools, procedures, and structures that generate information on malaria cases. The definition of a case in a malaria surveillance system will depend on whether it is syndromic (i.e. it relies on clinical symptoms only) or if suspected cases are diagnostically confirmed to be malaria cases (i.e. that a suspected case has a positive RDT test or a positively read microscopy slide). Such information can aid a public health program in planning, monitoring, and evaluating malaria control interventions. Design of a system will depend on the level

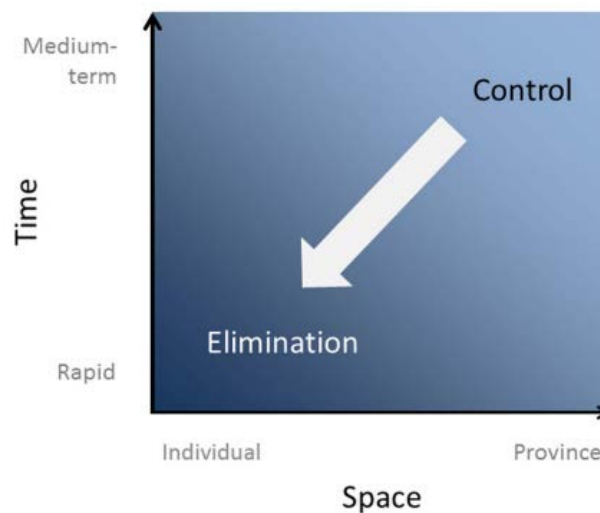
of transmission and resource constraints. For example, in the initial phase of malaria control, a high caseload will make it impossible to react to each individual confirmed case. However, transmission reduction makes it increasingly feasible to track and respond to cases individually (WHO 2012b).

The relationship between malaria transmission levels and surveillance consideration is more nuanced than this simplification. During mid-high transmission settings, the overarching goals for a malaria control program will be to reduce incidence. Surveillance systems in such a setting then aim to provide information on populations in which incidence is high (and to which populations resources should be targeted) (WHO 2012a). During lower transmission settings, elimination is the overarching goal. Surveillance systems here focus on detection of all cases in order to halt transmission. As a result, malaria cases themselves are defined very differently in these two surveillance settings. The remainder of the discussion will focus on surveillance for malaria elimination.

### **2.3.1 Surveillance for Elimination**

A key concern for surveillance efforts in low malaria endemic settings is the identification of asymptomatic and low-density or sub-patent infections. Both *P falciparum* and *P vivax* infections have a high chance to be asymptomatic in low transmission settings, especially if rapid reduction in malaria incidence was achieved (Okell, Ghani et al. 2009). Such asymptomatic and sub-patent cases are likely to be missed by surveillance and by traditional detection methods. While the former infections may never present themselves at health facilities, the latter will likely not be detected by microscopy or RDTs as such infections have parasitemia below the microscopic threshold. With subpatent infections in low-endemic settings estimated to cause 20-50% (Okell, Ghani et al. 2009) of all transmission episodes, failure to identify such cases, in addition to asymptomatic cases, can hinder transmission interruption efforts.

Thus, when a country transitions from control efforts to elimination efforts, surveillance needs to be significantly strengthened to provide rapid real-time information on all malaria infections, symptomatic and asymptomatic, in addition to geo-referencing of all cases (Sabot, Tulloch et al. 2009, Sturrock, Hsiang et al. 2013, Ohrt, Roberts et al. 2014). As a result, surveillance becomes an intervention in itself. Such extensive searching should occur in two stages: (1) identification of all areas or foci of local malaria transmission, which can be identified from case investigate of malaria cases from health facilities and (2) assessment of transmission characteristics of the focus if it is deemed to have a local origin (WHO 2012b). This transition in surveillance objectives for malaria surveillance is depicted in the Figure 8 below.



**Figure 7: Targetted surveillance and response in the shift towards elimination**  
**Source: (Ohrt, Roberts et al. 2014)**

Traditionally, countries have used passive case detection (PCD) to ascertain malaria endemicity, which requires a reliance on symptomatic patients presenting at health facilities for diagnoses and treatment. However as mentioned above, at near elimination levels, a substantial portion of malaria infections will be asymptomatic and sub-patent. This makes PCD insufficient to halt transmission, as undetected infections can contribute to onward transmission of malaria (Alonso,

Atta et al. 2011). It is important to mention here that while asymptomatic cases can be detected by altering surveillance operations, detecting sub-patent infections requires a shift in diagnostics used. A method for detecting asymptomatic cases is active case detection (ACD). This either involves the detection of cases by health workers at community and household level using fever screening followed by parasitological examination of all febrile patients, or parasitological examination of a target population without prior fever screening. This strategy is recommended by the World Health Organization (WHO) and seeks out residual parasite carriers, which can be particularly useful for capturing asymptomatic infections (WHO 2012b). These PCD and ACD surveillance activities may either be syndromic or they may rely on diagnostic tests, such as RDT or blood slide microscopy.

### **2.3.1.1 Importance of Detecting Case Clustering Increases**

Malaria infections in all transmission settings tend to be clustered geographically. Such variation in the risk of malaria between villages in endemic regions has long been recognized (Snow, Rowan et al. 1988, Greenwood 1989). While disease clustering is common for many infections and parasitic diseases, where a small number of human hosts are more frequently infected, this phenomenon is exemplified in malaria. Micro-epidemiological variations in malaria incidence are most pronounced in low transmission settings (Woolhouse, Dye et al. 1997, Bousema, Griffin et al. 2012, Rulisa, Kateera et al. 2013). Two distinct geographical units of malaria transmission are Foci and Hotspots and can be defined as the following:

- Foci: A focus is situated in a currently or former malarious area containing continuous or intermittent epidemiological factors and is considered active when the local *Anopholes* population sustains the basic reproductive rate ( $R_0$ ) at a level above 1 (WHO 2007). The size of the focus depends on the mosquito-breeding site, and its border is the furthest location where malaria is still supported by the breeding site.

- Hotspot: A hotspot is a geographical portion of a focus in which malaria transmission intensity exceeds the average level of the focus ( $R_0$ ). While the size of a hotspot is variable, it is typically less than 1 km<sup>2</sup> and its borders are identified where transmission is no longer higher than the average of a focus (Bousema, Griffin et al. 2012).

Hotspots are particularly relevant for malaria control and elimination. When they remain untargeted they are likely to be areas where residual malaria transmission persists and play a catalyzing role in contributing to onward transmission (Bousema, Griffin et al. 2012). Detecting hotspots becomes essential to elimination efforts and can be done so through micro-epidemiological elevations in incidence (Bejon, Williams et al. 2010, Bousema, Drakeley et al. 2010), asymptomatic parasite carriage (Ernst, Adoka et al. 2006, Bejon, Williams et al. 2010)..., and serological response to malaria antigens (Bousema, Drakeley et al. 2010, Bousema, Youssef et al. 2010), among others (Bousema, Griffin et al. 2012). However the most robust indicator is a clustering of asexual parasite carriage and malaria-specific immune responses rather than clinical malaria episodes (Bousema, Griffin et al. 2012), as high exposure in hotspots can result in faster immunity development (Bejon, Williams et al. 2010) and antibody responses usually only occur due to prolonged exposure (Bousema, Drakeley et al. 2010).

### **2.3.1.2 Increased Utility of Active Case Detection**

PCD, in which malaria cases are captured when individuals attend health clinics, is only able to detect cases that are symptomatic and see the necessity of visiting a clinic. ACD, on the other hand, takes advantage of the spatial clustering of malaria cases. Using index cases as a point of reference, ACD targets hotspots and ‘hotpops’, or at-risk populations, to seek out asymptomatic cases and residual parasitemia within the population. Currently, ACD can be split into two broad types:

- Reactive Case Detection (RACD): This takes advantage of the fact that parasitic carriage tends to be spatially and temporally clustered. Thus, infections are found at higher prevalence in households in which an index case resides and households in close proximity. Moonen, Cohen, et al. (2010a, p. 1594) describes RACD as “triggered whenever a case is identified from passive case detection...and will involve visiting the household of a locally acquired case, screening household members, and surrounding households.” Malaria programs have used multiple screening radiuses and as of yet, the most efficient radius is unknown. This largely depends on the resources a malaria program has and the prevalence of malaria.
- Proactive Case Detection (PACD): This involves the preemptive screening of high risk populations and areas and has been found to reduce transmission (Gueye, Sanders et al. 2013).

Many countries have attempted or are implementing ACD to achieve and maintain malaria elimination, each with their own unique strategy (Macauley 2005, Hsiang, Hwang et al. 2012, Sutcliffe, Kobayashi et al. 2012, Yangzom, Gueye et al. 2012). However, there is more evidence on the effectiveness of RACD. For example, RACD in Zambia found an 8% prevalence of malaria within index households as compared to 0.7% within randomly selected houses (Stresman, Kamanga et al. 2010)..

## **2. 4 Summary**

Public health surveillance has been practiced since the mid-14<sup>th</sup> century, and has developed to include individual case surveillance in addition to statistical surveillance. The expansion of considering surveillance as a means to monitor the health of a population created a link between surveillance and public health practice, a bond that has been emphasized by public health academics and practitioners alike. Surveillance is now considered as an essential function of a public health

system. By quantifying severity and trend of a public health concern, surveillance has the ability to contribute to an evidence-based public health. This is only possible if the data collection procedure in a surveillance system is of high quality. Key metrics of any data collection procedure in a surveillance system are timeliness and completeness. The main data collection procedures used in surveillance systems are: 1) passive surveillance, 2) active surveillance, 3) sentinel surveillance, 4) syndromic surveillance, and 5) the use of secondary data.

Timeliness and completeness become vital for a malaria surveillance system as program efforts transition from control to elimination. At lower transmission levels, malaria becomes characterized by micro-epidemiological traits, making the timely identification of all malaria cases crucial. An ideal surveillance system for malaria elimination would emphasize real time data collection on all cases in addition to a geo-location of all cases. While countries seeking malaria control have traditionally used PCD as a surveillance method, elimination efforts require ACD to detect not only cases that may not otherwise present themselves at health facilities but also hot spots of malaria. This will enable malaria programs to develop a better understanding on the true level of malaria in a country and target malaria interventions more strategically.

## 3.0 Zanzibar Background, Malaria Epidemiology & Malaria Control History

### 3.1 Zanzibar Background

Zanzibar is a semi-autonomous region of the Republic of Tanzania and is located in East Africa. It is composed of an archipelago of islands, with its two biggest called Unguja and Pemba. The climate of Zanzibar is equatorial and humid, with two main rainy seasons. The first is a long period (Masika) lasting from March to June and the second is a shorter period (Vuli) that lasts from October to December. However, the rain patterns differ between the two islands, with Pemba experiencing a uni-modal season and Unguja experiencing a bi-modal season (ZMCP 2009).

Zanzibar is divided into 5 administrative regions, three in Unguja and two in Pemba. Those in Unguja are called Zanzibar Central/South, Zanzibar North, and Zanzibar Urban/West. Those in Pemba are called Pemba North and Pemba South. Each administrative region is further divided into two districts, making a total of 10 districts in the region. Zanzibar has the following districts: Urban, West, Central, South, North A, and North B. Pemba is divided into the districts of Michweni, Mkoani, Chake Chake, and Wete (MOHSW 2009). The organization of the administrative structure to the district level can be seen below in Table 1. Below the district level, at the lowest administrative structure, is the Shehia, which is located at the community level.

**Table 1: Administrative Regions & Districts of Zanzibar**

Island	Administrative Region	District
Unguja	Central/South	Central
		South
	Urban/West	Urban
		West
	North	North A
		North B
Pemba	North	Wete
		Micheweni
	South	ChakeChake
		Mkoani

### **3.1.1 Health System**

The public health system of Zanzibar relies on three levels of health care centers. The first and lowest level contains Primary Health Care Units (PHCU) and Primary Health Care Centers, also known as the cottage hospitals. The second level consists of district hospitals and the third and last level consists of the referral hospital. While there is only one referral hospital, there are numerous PHCUs. It is these units that form the backbone of Zanzibar's public health system and provide basic health services to the population. This dense network is split into two types: PHCUs and PHCU+s. While PHCUs only offer basic health services, PHCU+s offer deliveries, dental care, and laboratory services in addition (MOHSW 2010).

### **3.2 Malaria Epidemiology**

Until recently, malaria in Zanzibar was characterized by perennial stable transmission. However, the introduction of various interventions including Artemisinin-based Combination Therapy (ACT), the use of long-lasting insecticide treated nets (LLINs), and high coverage of indoor residual spraying (IRS) has changed endemicity patterns from hyper to hypo-endemic (Bhattarai, Ali et al. 2007). Malaria transmission has declined significantly in Zanzibar, from 35-40% prevalence in 1995 (ZMCP 2009) to less than 1% as of 2012 (TACAIDS 2012).

The predominant species of the malaria parasite is *Plasmodium falciparum*, accounting for 96% of all malaria infections. The only other malaria species found in Zanzibar is *Plasmodium malariae* (ZMCP 2009) and the only malaria vectors found in Zanzibar are *Anopheles gambiae sensulato*, *An. fenestus*, and *An. Constani* (ZMCP 2009). Zanzibar has the characteristics of a pre-elimination country. Not only is it at the margins of a malaria-endemic region but its malaria transmission has been reduced and incidence is also low (Feachem, Phillips et al. 2010). The current innate transmission risk has been calculated to have an  $R_0$  between 10-15 and the  $R_C$  being close to 1 (ZMCP 2009), with it ranging between 0-0.56 in urban Unguja, 0.71-0.91 in rural Unguja, and 0.92-0.97 in Pemba (Le

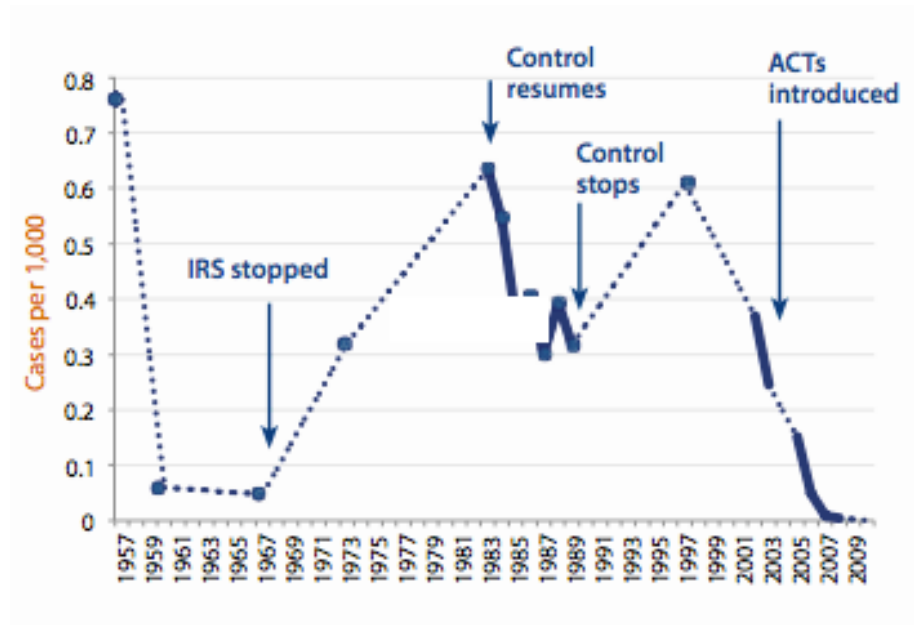
Menach, Tatem et al. 2011). While this indicates that interventions have been highly successful, it also signifies the risk of rising malaria prevalence if control efforts are relaxed (ZMCP 2009).

### ***3.3 Historical Efforts for Malaria Control (1960s-1980s)***

Zanzibar has a storied history with malaria control efforts. Control and eradication attempts were mounted twice. While they were both successful in reducing malaria prevalence, political will reduced with decreasing prevalence. As a result, prevalence rose significantly as control efforts were relaxed. Zanzibar's first full-scale malaria control program was initiated in 1958 through a collaboration with the government of Zanzibar, the World Health Organization, and the UN Children's Fund (USAID 1983). This was expanded during 1961-1968 and reduced prevalence to 7.8% in Unguja 1.7% in Pemba (Schwartz, Pener et al. 1997). The successful reduction came with costs. After malaria was declared as no longer a health concern, the control program was abandoned in 1968 and by 1973 and prevalence rose to 54% in Unguja and 10% in Pemba (Schwartz, Pener et al. 1997).

In line with a rising global interest in malaria reduction, Zanzibar initiated its next control program in 1981 with the support of the United States Agency for International Development (USAID). Scheduled to expire in 1987, this program was originally designed to reduce the prevalence of malaria to a level where the government of Zanzibar could maintain control with its own resources. As ambitious as this program was, it was organized without a vector control specialist (AFM 2008). This drawback complicated the implementation of the program, which explicitly focused on IRS as an intervention. Possibly as a result of uncoordinated spraying schedules and irregular supply of insecticide (USAID 1983), reports noted growing resistance to insecticide. This, in addition to the development of drug resistance to chloroquine, the first line treatment, hampered control efforts (AFM 2008). This was followed by poor communication between USAID and the Zanzibar government, resulting in procurement of insecticides unsuitable for IRS. As a result of

these failings, the project was terminated in 8 years in 1989. Once again, malaria cases rose, from 23.2% in 1989 to over 60% in 1994 in the Island of Pemba (Cohen, Smith et al. 2012). The figure below depicts the reductions in malaria from control programs and resurgence events since Zanzibar’s first malaria program in 1958 and includes the recent aggressive campaign launched in 2004, which will be discussed in the section below.

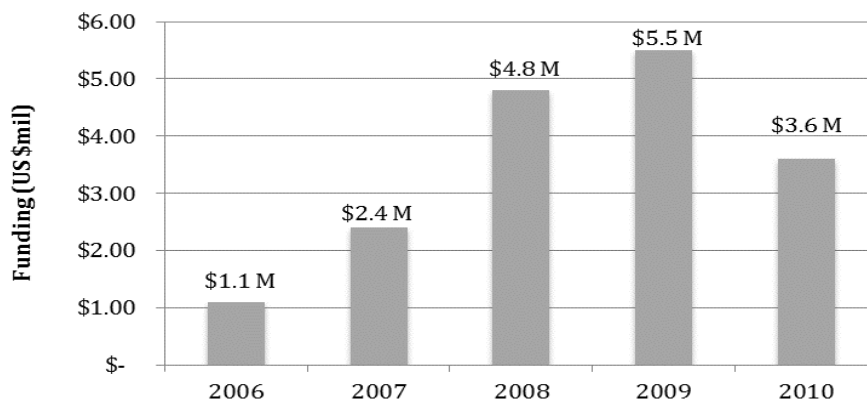


**Figure 8: Malaria Control and Resurgence in Zanzibar (1950s-2009)**  
Source: (E2Pi 2011)

### **3.4 Recent Malaria Control Efforts (2003-Present)**

Zanzibar’s Ministry of Health and Social Services responded to growing chloroquine resistance by declaring a shift from its use as a first and second line treatment to artemisinin based combination therapies (ACT). This policy was adopted in September 2003 (Bhattarai, Ali et al. 2007), supported by a Global Fund grant with a lifetime budget of \$1,153,080 (Global Fund 2006). Additional support from the Global Fund in 2005, amounting to a lifetime grant of \$8,438,788, was used to continue the artemisinin treatment policy and scale up of coverage of bed nets (Global Fund

2009). Just a year later, the islands of Zanzibar, in addition to mainland Tanzania, were selected to join the newly formed U.S. President’s Malaria Initiative (PMI) (PMI 2006). As a result, Zanzibar received support for a comprehensive three round IRS schedule, 100,000 RDTs for diagnostic use at public health facilities, and 340,129 LLINs between 2005-2007 (PMI 2007). The influx of funds and other development assistance aided Zanzibar’s malaria control efforts, and in between 2002 and 2005, the combination of ACTs and bed-nets reduced malaria related deaths among children under the age of 5 by 75% (Bhattarai, Ali et al. 2007). By 2007 it was estimated that laboratory confirmed cases at health facilities dropped to 1% (PMI 2007). Donor spending was a critical catalyst in the scale up of interventions in Zanzibar. Figure 10 depicts the financial support that Zanzibar has received for malaria control from 2006-2010. The bulk of these financing streams have come from PMI, 58%, and the Global Fund, 39%. The remaining 3% of funding for malaria control comes from WHO, UNICEF, the government of Zanzibar, and other donors (E2Pi 2011).



**Figure 9: Malaria Control Development Support 2006-2010**  
Source:(E2Pi 2011)

### **3.5 Current Status & Future Directions**

Over the past several years, Zanzibar has made dramatic progress in reducing the burden of malaria and has reduced prevalence to less than 1% according to the 2011-2012 Tanzania HIV-

Malaria Indicator Survey (PMI 2015). While development aid supported the scale-up of interventions that drove down prevalence, a large amount of this success can be attributed to a surveillance system that Zanzibar created in 2008, the Malaria Early Epidemic Detection System (MEEDS). This system was created in collaboration with PMI and the CDC and RTI. MEEDS allowed Zanzibar to track weekly aggregates of case data to alert public health officials of hotspots. 150 health facilities in Zanzibar currently use MEEDS to report all diagnostically confirmed cases detected within incoming patients, making it an example of passive case detection. MEEDS uses cell-phone based reporting via unstructured supplementary service data (USSD)<sup>1</sup>, and interactive text based program (RTI 2013b). A public-private partnership between the Zanzibar malaria program and Selcom Wireless facilitates data transmission and storage (RTI 2009). An example of text-based screens can be seen in Appendix 3. These data are automatically transferred to ZMCP and if an abnormal rise in malaria cases is detected, the ZMCP sends a response team to hotspots to conduct a focal screening and treatment (FSAT)<sup>2</sup> (PATH 2014).

The dramatic reduction in malaria prevalence brought the Zanzibar Malaria Control Program (ZMCP) to a crossroads. It could seek to sustain its current control operations to keep malaria suppressed, or it could attempt to eliminate malaria from the islands altogether. To move forward, Zanzibar conducted a feasibility assessment for elimination in the region. Findings indicated that elimination is possible with currently available interventions. Furthermore, findings also indicated that elimination would be operationally challenging to prevent reintroduction if importation

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<sup>1</sup> USSD: Like text messages, USSD texts allows for the exchange of messages between two parties. However, instead of the recipient of a USSD message being another mobile phone the recipient is a mobile application. Additionally, USSD messages transactions only occur during the session and cannot be stored, which makes it useful for the exchange of sensitive and proprietary information. Sessions are initiated by using a short code (\*101#)

<sup>2</sup> FSAT: This refers to the screening of all individuals within an identified focus. All individuals who are diagnostically confirmed to have malaria are provided treatment.

risk remains high. Lastly, the feasibility assessment determined that elimination would require maintaining control efforts and support by a robust surveillance system (ZMCP 2009).

With these findings, Zanzibar launched its malaria-elimination program in 2013 to replace its control program. The newly created Zanzibar Malaria Elimination Program (ZAMEP) heads the region's efforts, with the 2013-2018 Strategic Plan outlining a goal of achieving 'zero locally acquired cases' by 2018 (ZAMEP 2012). To support its elimination goal, Zanzibar followed the recommendation outlined in the feasibility assessment to implement a robust surveillance system. The new surveillance system, termed Malaria Case Notification (MCN), was established in 2012 and tracks malaria cases daily. This builds on the strengths of MEEDS and makes use of the same mobile devices technology to support its efforts. Chapter 5 will present a description of the MCN system.

### **3.6 Summary**

Zanzibar, a semi-autonomous region of Tanzania, has had a storied history with malaria. The predominant parasite of malaria in Zanzibar is *P. falciparum* and the predominant vector is *A. gambiae sensulato*, *A. fenestus*, and *A. Coustani*. While currently having the characteristics of a pre-elimination country, including not only being located at the margin of the malaria endemic region but also having low malaria transmission, Zanzibar has had mixed success in controlling malaria in the past. With control efforts first being implemented in 1958, a cycle of intervention implementation and relaxation up to 1989 caused malaria prevalence to fall and resurge. However, the rise of global malaria partnerships and global funding agencies dedicated towards malaria brought considerable technical and financial support for the most recent wave of malaria control efforts in Zanzibar. Prevalence rates have been brought down to less than 1% according to a recent 2012 HIV & Malaria Indicator Survey.

The recent reductions in malaria brought Zanzibar to a crossroads, where it could either pursue sustained control or strive for malaria elimination. The results from a malaria elimination

feasibility assessment indicated that while elimination was possible with the currently available interventions, it would require strict maintenance of control efforts in addition to a robust surveillance system. With these findings, Zanzibar established its elimination program, ZAMEP, in 2013, and its new surveillance system, MCN, in 2012. Building on the strengths of MEEDS, MCN enables ZAMEP to track malaria cases daily.

The details of how MCN functions will be discussed in the next chapter.

## **4.0 Zanzibar's Malaria Case Notification (MCN) Surveillance System**

The dramatic reduction in malaria prevalence to <1% by 2012 vaulted Zanzibar to a pre-elimination setting. To identify the next steps for its malaria control program, an elimination feasibility assessment was conducted, and its findings indicated that malaria elimination was possible if control measures were maintained and a robust surveillance system was implemented. As a result, Zanzibar strengthened its surveillance system to allow for daily case reporting by creating Malaria Case Notification (MCN). MCN utilizes the same USSD technology in MEEDS and integrates an additional mobile-based technology called Coconut Surveillance (RTI 2013c).

MCN reacts to a rise in cases but also has the added benefit of providing real time data. In addition from transitioning malaria surveillance from aggregate reporting to a case-based reporting, MCN engages in surveillance activities beyond passive case detection at the health facilities. Each diagnostically confirmed index case reported from health facilities becomes a source for reactive case detection, and MCN follows-up on each diagnosed case to the household to detect additional cases (RTI 2013c). To support follow-up activities, ZAMEP hired a new cadre of health care workers called District Malaria Surveillance Officers (DMSOs) who are responsible for responding to each case reported in their district. There are currently two DMSOs per district, making a total of 20 DMSOs in Zanzibar (PMI 2015).

### **4.1 Data Production Stakeholders**

Two groups of stakeholders are integral to the data production process within the MCN surveillance system: Health Facilities, and DMSOs. Without their concerted efforts, data flow from diagnosis to response would be disrupted. While the health facilities are primarily responsible for diagnosis and case reporting, DMSOs are responsible for case-confirmation and case follow-up.

As of 2014, 156 health facilities participate in MCN reporting, which consist of all public health facilities and some larger private facilities. ZAMEP is in the process of expanding MCN to cover all private facilities (PMI 2015). To support malaria diagnosis and reporting, ZMEP provides public facilities with diagnostic tools (microscopy and RDTs), recording ledgers (daily malaria case registers), and reporting tools (a cell phone) (PATH 2014). The diagnostic method used by health facilities varies in Zanzibar and depends on the level of health facility. Table 2 below summarizes the distribution of diagnostic tools within the health system (PATH 2014).

**Table 2: Diagnostic Tools Used in Zanzibar**  
**Source: (PATH 2014)**

<u>Health Facility Level</u>	<u>Diagnostic Tool</u>
Primary Health Care Unit (PHCU)	RDT
Primary Health Care Unit (PHCU+)	RDT & Microscopy
Primary Health Care Center (PHCC)	Microscopy
District Hospital	Microscopy
Referral Hospital	Microscopy

Though health facilities were a component of MEEDS, DMSOs are a new component in MCN. After a case has been notified to the system, DMSOs are tasked with following-up on each case to both the health facility and household of the index case (Ohrt, Roberts et al. 2014, PATH 2014).

## **4.2 Patient/Data Flow**

The data within MCN flows through a mix of passive case detection (PCD) and reactive case detection (RACD). Health facilities participate in PCD and DMSOs participate in RACD. While the data flow is roughly divided into these two portions, the PCD and RACD segments have multiple steps that are explained below.

### **4.2.1 Passive Case Detection**

The flow of data within MCN starts at the health facilities. If a patient presents with fever, local health care providers use either a rapid diagnostic test (RDT) or blood-slide microscopy to test for malaria. Diagnostically confirmed cases are then recorded in a malaria case register (MCR) and reported to ZAMEP. Daily reporting uses a USSD notification system to transmit data and is ideally done within 24 hours of diagnosis (PATH 2014). When a USSD notification is sent, the following data are transmitted with it: an automatically generated Case ID, the name of the patient, the health facility, and district (Cressman, McKay et al. 2014). Within the MCR, additional information is recorded on patient's contact information and location to facilitate RACD by DMSOs.

### **4.2.2 Reactive Case Detection**

Once a USSD Notification is sent, Coconut Surveillance is initiated. The DMSO, using an Android Tablet with the Coconut Surveillance application, is able to access the system. Each DMSO is notified of a newly reported case in their district via a text alert on their mobile phone and Case Notification on their tablet. The latter can be seen in Figure 11 below. After accepting the notification, the RACD process begins and Coconut Surveillance provides DMSOs a guided protocol through the follow-up process at the health facility, index case household, and all household members. This guided protocol can be seen in Appendix 4.1. All information collected during the follow-up process and transmitted to ZAMEP can be seen in Appendix 5.

Field	Value
question	Case Notification
MalariaCaseID	103287
FacilityName	CHARAWE
Shehia	CHARAWE
Name	
createdAt	2014-03-27 12:14:41
lastModifiedAt	2014-03-27 12:14:41

**Figure 10: Coconut Surveillance Case Notification**  
**Source: (Cressman, Mckay et al. 2014)**

#### 4.2.2.1 Health Facility

At the health facility level, DMSOs are responsible for confirming all reported cases; collecting additional diagnostic information, such as parasite species and the date of positive results; and collecting data on patient contact information and location. Follow-up at the health facility should be done within 24 hours of receiving a USSD Notification (Cressman, Mckay et al. 2014, PATH 2014). This information is essential not only for the follow-up process and but also for ZAMEP to determine epidemiological trends and possible hotspots of malaria. A portion of the screen that DMSOs use when following-up at the health facility can be seen below in Figure 12.

The screenshot shows a form titled "Facility" with a "Help" button in the top right corner. The form contains the following fields and values:

- Facility Name: CHARAWE
- Malaria Case ID: 103287
- Date of Positive Results: (empty field)
- Parasite Species: PF (highlighted in blue)
- Reference # in OPD Register: (empty field)
- First Name: (empty field)
- Middle Name: (empty field)

**Figure 11: Coconut Surveillance Health Facility Follow-Up**  
**Source:(Cressman, Mckay et al. 2014)**

#### 4.2.2.2 Household

After the health facility follow-up, DMSOs use the information collected to locate the index case. Upon arriving at the household, DMSOs geo-locate the house and collect information on the penetration of malaria interventions (bed net use and last IRS date) in addition to the number of household members and those with malaria (Ohrt, Roberts et al. 2014, PMI 2015). Completing the information on the household involves testing all household members for malaria. Thus, before the household step is completed in Coconut Surveillance, the next step of the guided protocol has to be completed. A portion of the Coconut Surveillance screen used for the household follow-up can be seen in Figure 13 below.

The screenshot shows a mobile application interface for a household follow-up. The title is "Household" with a "Help" button in the top right. The form contains several fields with labels on the left and input areas on the right. The "Reason for visiting household" field is set to "Index Case Household". The "Household Location" field has a "Get current location" button. The "Location Description" field is empty. The "Success" field has a "Success" button. The "latitude" field contains "-6.111111111111111". The "longitude" field contains "39.11111111111111". The "accuracy" field contains "21". The "Followup Neighbors?" field has a dropdown menu with "Yes" and "No" options, where "No" is selected. The "Total Number of Residents in the Household" field contains "5". The "Number of LLIN" field contains "2". The "Number of Sleeping Places (beds/mattresses)" field is empty.

Field Label	Value
Reason for visiting household	Index Case Household
Household Location	Get current location
Location Description	
Success	Success
latitude	-6.111111111111111
longitude	39.11111111111111
accuracy	21
Followup Neighbors?	No
Total Number of Residents in the Household	5
Number of LLIN	2
Number of Sleeping Places (beds/mattresses)	

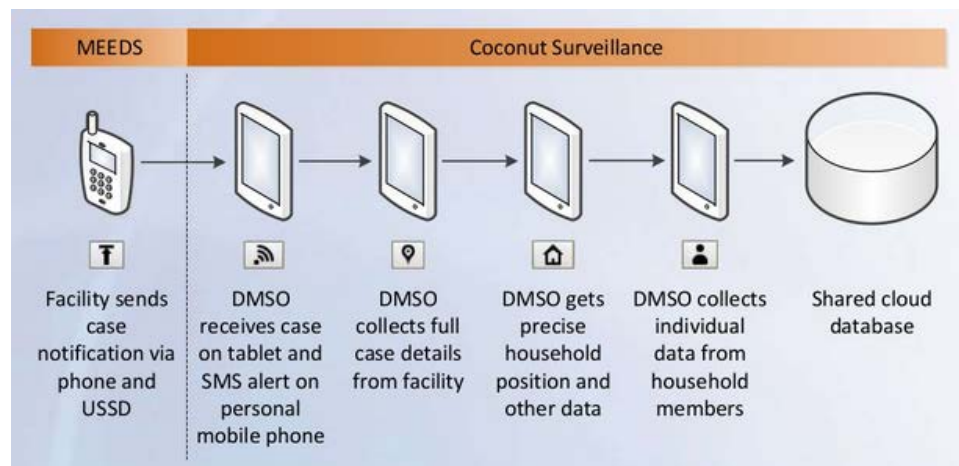
**Figure 12: Coconut Surveillance Household Follow-Up**  
Source: (Cressman, Mckay et al. 2014)

### 4.2.2.3 Household Members

The last step of RACD in MCN is the testing of all household members in the index case household. This portion of MCN has the ability to capture possibly asymptomatic cases of malaria or those that may not be detected by PCD as quickly. The information collected here includes age, gender, travel history, and RDT test results of all household members. This process can be time intensive as the average household has between 5-10 members (PATH 2014).

## 4.3 Integration of USSD and Coconut

Once a USSD notification is sent by health facilities, the server the data are stored on are sent automatically to the Coconut Surveillance application. The DMSO who is assigned to the district in which the case was detected receives a case notification on their tablet and is guided through the follow-up process. This process is depicted in Figure 14 below. Throughout the follow-up process, data are synced and aggregated in the cloud, making monitoring data flow possible. The online portal for monitoring data flow can be seen in Appendix 4.2.



**Figure 13: Integration of USSD Notifications and Coconut Surveillance**

**Source: (Cressman, Mckay et al. 2014)**

ZAMEP uses the data collected through MDN to map hotspots and implement interventions. Furthermore, the data are aggregated and disseminated via quarterly reports to health

facilities in order to provide information on the functioning of MCN. (PMI 2015). The design of Coconut Surveillance acknowledges that there may be unreliable access to the cloud. To accommodate this reality, Coconut Surveillance allows for data collection to occur offline without disruption to how data and their timestamps are recorded. Furthermore, it automatically sends data when a connection is available (RTI 2013a).

#### **4.4 Summary**

Zanzibar's new malaria surveillance system, MCN uses two surveillance strategies, PCD and RACD, in conjunction with each other. The two main groups of stakeholders that contribute to MCN are health facilities and DMSOs, with health facilities engaging in PCD and DMSOs engaging in RACD. While MCN uses the USSD messages for PCD that MEEDS utilized, it incorporates another mobile device technology, Coconut Surveillance, to aid RACD efforts. The latter enables ZAMEP to geo-locate where positive cases of malaria reside. Furthermore, it allows ZAMEP to collect information on the household of this index case and test household members for malaria. This information allows ZAMEP to identify the penetration of interventions as well as assess their effectiveness. Furthermore, it enables ZAMEP to rapidly detect and respond to hotspots of malaria transmission.

MCN is a core program of ZAMEP's public health enterprise for malaria elimination. For Zanzibar to achieve its elimination goals by 2018, MCN has to operate effectively. As such, a performance evaluation must be conducted to highlight not only its strengths but also its weaknesses. MCN is a surveillance system meant to support malaria elimination and should be capturing cases rapidly. Thus, timeliness will be a critical metric of this performance evaluation.

The next chapter will discuss the development of performance evaluation in public health, the orthogonal development of evaluation of surveillance systems, and describe the current body of research on the evaluation of timeliness of surveillance systems.

## **5.0 Literature Review**

Public health practice is credited with providing large strides in human development and gains in life expectancy. Through advances in the field such as, public health legislation, epidemiology, and disease control, public health practice has provided a variety of population health management interventions (Brownson, Fielding et al. 2013). However, the success of public health has not been consistent throughout the world, with many populations still suffering basic access to health care, clean water, and sanitation. If developments in public health want to be continued, public health programs and officials need to reach beyond the low hanging fruit. A means to do so has been percolating in academic and grey literature: evidence-based public health (EBPH).

### **5.1 Evidence Based Public Health**

EBPH finds its roots in evidence based medicine (EBM) (Jenicek 1997, Brownson, Gurney et al. 1999), a field formally introduced by the Evidence-Based Working Group (1992) While the wide following of EBM gave birth to a number of other evidence based approaches, Jenicek (1997) used the epidemiological principles that EBM grounded itself in to illustrate that public health practice could also use the same “conscientious explicit, and judicious use of current best evidence (Sackett, Rosenberg et al. 1996, p. 71)” to make decisions. While public health practice is by its nature characterized as evidence based, it is more complex than the clinical interventions based on EBM.

Since introduced in 1997, EBPH has been elaborated upon by scholars and practitioners which has increased its uptake and identified sources of evidence (Brownson, Baker et al. 2011b). The most recent and accepted definition of EBPH was proposed by Kohatsu, Robinson et al. (2004, p. 419) as “the process of integrating science-based interventions with community preferences to improve the health of populations.” Based on this new definition, the defining attributes of EBPH have come to include (Brownson, Fielding et al. 2013):

- Making decisions using the best available peer-reviewed evidence (both quantitative and qualitative)
- Using data and information systems systematically
- Applying program-planning frameworks (based in behavioral science theory)
- Engaging the community in assessment and decision making
- Making sound evaluations
- Disseminating what is learned to key stakeholders and decision makers

### **5.1.1 Evidence Base & Analytical Tools**

At the heart of the defining attributes and the above framework is the ‘best available evidence.’ The scientific evidence relevant to public health can be divided into three categories: Type 1, Type 2, and Type 3. Type 1 usually defines causes of disease and the severity of diseases. Type 2 describes the type and degree of impacts interventions have. Type 3 evidence provides information on the contexts in which interventions work (Brownson, Baker et al. 2011b). These three categories of evidence are summarized in Table 3 below. While this typology of public health evidence is well understood, the evidence itself is underpopulated (Millward, Kelly et al. 2003). For example, while there is ample Type 1 evidence, resulting from epidemiological research, there is a paucity of Type 2 evidence (Sanson-Fisher, Campbell et al. 2008) and Type 3 evidence (Brownson, Baker et al. 2011b). In filling this gap, large scale impact evaluations have been guided by the ‘gold standard’ of randomized control trials (RCTs). However, it has been argued that RCTs may not provide appropriate assessment of public health practice performance (Victora, Habicht et al. 2004). As a result, public health programs and practitioners have turned to the following analytical tools: systematic reviews & evidence based guidelines, economic evaluation, health impact assessments, participatory approaches, and public health surveillance (Brownson, Fielding et al. 2009)

**Table 3: EBPH Evidence Types**

<b>Characteristic</b>	<b>Evidence Type</b>		
	<u>Type 1</u>	<u>Type 2</u>	<u>Type 3</u>
<u>Typical Data</u>	Size & Strength of Risk	Effectiveness of Intervention	Adaption and Translation of Effective Intervention
<u>Setting</u>	Clinical or Controlled Community Setting	Community Setting	Community Setting
<u>Causal Action</u>	“Something should be done”	“This intervention should be implemented”	“How & where an intervention should be implemented”

### 5.1.1.1 Analytical Tools for EBPH

Gather evidence for EBPH should rely on a variety of tools. Doing so can lead to the triangulation of evidence, which after drawing upon multiple sources of complementary data, can provide in depth insight on a topic (Brownson, Baker et al. 2011b). The following analytical tools are starting to be used by public health programs to build an evidence base:

- **Systematic Review:** These are syntheses of information on a topic which provide a comprehensive overview. These usually seek to answer what interventions have been implemented and what their effects have been; what aspects of interventions have been instrumental for their effectiveness; and what their possible costs are (Brownson, Baker et al. 2011b). In addition to providing a surfeit of Type 2 evidence, systematic reviews should ideally lend to Type 3 evidence by clarifying contextual conditions critical for the success of the intervention (Waters and Doyle 2002).
- **Economic Evaluation:** This tool is a critical tool for EBPH, as if conducted ex ante can provide information on the economic value of multiple interventions. This tool considers financial costs of a program and monetizes both societal costs and benefits to present the

net benefit to society of a program. If conducted well, economic evaluation can make selection of program relatively easy; the program with the highest net benefit or lowest cost per unit of desired outcome is best choice.

- Health Impact Assessment: This is relatively new tool and embodies the concept of ‘societal determinants of health’ by estimating the impact on health from a policy in non-health sectors. HIAs currently conducted cover a wide range of topics, such as wages, after school programs, and public projects (Dannenberg, Bhatia et al. 2008).
- Participatory Approaches: This tool represents the community preferences component of the definition of EBPH that Kohatsu, Robinson et al.(2004) introduced, by actively involving the community in intervention projects (Cargo and Mercer 2008). Public health officials build upon existing resources through community input and integrate this new knowledge into public health practice to realize a fair distribution of benefits (Brownson, Fielding et al. 2009).
- Public Health Surveillance: Mostly used to gather Type 1 evidence, public health surveillance is an important tool for EBPH. When linked to public health action, surveillance data have resulted in life saving interventions. For example, blood level surveillance data in the U.S. justified lead abatement policies (Brownson, Baker et al. 2011b). Furthermore, public health surveillance can also be used to monitor the effectiveness of interventions, making it an extremely robust tool for EBPH. However, while public health surveillance is a tool to gain evidence, it is also an essential component of public health practice as such it should be deemed a public health program in itself (Nsubuga, White et al. 2006).

## **5.2 Public Health Services and Systems Research: A Means to Evaluate Evidence Based Public Health**

While the aforementioned tools can shed light on key public health needs and possible interventions, they do little to assess the performance of public health programs. This can be accomplished by program evaluation, an essential organizational practice in public health (Dyal 1995, CDC 1999) that investigates how a program is being delivered (process evaluation) and the extent to which a program is operating in relation to its benchmarked objectives (impact evaluation) (Brownson, Baker et al. 2011a). There are a variety of methods used in program evaluation for public health; however there is a growing body of research called Public Health Services and Systems Research (PHSSR) which focuses on public health workforce, public health system structure and performance, public health financing and economics, and public health information and technology.

### **5.2.1 Origins**

Just as EBPH finds its roots in EBM, PHSSR is related to health services research (HSR), a field of inquiry that focuses on medical care delivery. A key event that instituted the backdrop of PHSSR was the 1988 Institute of Medicine (IOM) report, *The Future of Public Health* (Lenaway, Halverson et al. 2006, Schutchfield, Marks et al. 2007), which established three core functions of public health: assurance, assessment, and policy development (IOM 1988). These three core functions were later expanded upon to develop a set of 10 essential public services (Turnock and Handler 1995), a process mirroring the trend of the Pan American Health Organization (PAHO) (Bettcher, Sapirie et al. 1998) and the World Health Organization (WHO) (Leowski 1998) formalizing the functions of public health (Schutchfield and Ingram 2013). These lists of functions can be seen in the table below:

The development of a consensus list of essential public health services spurred interest in examining public health system performance, which initially primarily focused on local public health

performance in the U.S. However, as interest in these essential services gained momentum, the performance measurement instruments started to be produced, such as the *20 Core Function-Related Measures of Local Public Health Practice Performance* (Turnock, Handler et al. 1998). However, the most important performance metrics that emerged was the National Public Health Performance Standards Program (NPHPSP) performance instruments in 2002, a critical juncture for the development of PHSSR as it “expanded the scope of performance measurement beyond the local community (Schutchfield and Ingram 2013, p. 5).” The national efforts in the U.S. to measure the performance of its public health system have been mirrored by PAHO (PAHO 2008) and WHO efforts (Schutchfield and Ingram 2013).

### **5.2.2 PHSSR Focus**

PHSSR initially focused on the roles and functions of public health agencies (Miller, Moore et al. 1994, Ford, Duncan et al. 2003). However, as the field developed, research expanded to not only define what a public health system is but also to investigate partnerships within public health and other entities (Lenaway, Halverson et al. 2006). Clear boundaries identifying PHSSR remained hazy, however. These became elucidated slightly in a critical study by Harris, Beatty, et al. (2011) which mapped the field of PHSSR using 11 key seed articles. Examining 2986 articles, the authors found 4 clusters within the field of PHSSR. The core of the research field consisted of studies investigating local health department effectiveness and activities. At the outskirts were research efforts investigating behavioral interventions, public health law, and the National Public Health Performance Standards Program (Harris, Beatty et al. 2011).

This blossoming of research in PHSSR was catalyzed by a IOM report in 2002 titled *The Future of the Public's Health in the 21<sup>st</sup> Century* which emphasized the need for PHSSR. The IOM report created a sea change in the amount of research being conducted in PHSSR, with organizational support coming from the Robert Wood Johnson Foundation and the University of Kentucky College

of Public Health (Schutchfield and Ingram 2013). Despite rising tide of academic interest in PHSSR, the field remained disorganized, and there were many calls for a research agenda. The CDC in 2003 proposed such an agenda in a list of research priorities. However, rapid developments in the field and healthcare environment prompted the development of a new agenda (Schutchfield, Perez et al. 2012).

In response, nine experts in the field of PHSSR convened to develop empirical research questions that could further guide the development of PHSSR. To guide their inquiry, the researchers considered the concept of a *public health delivery system, public health strategy, and performance of public health delivery*. Using the 2002 IOM report as a foundational text, the researchers established that a public health delivery system was “the full array of organizations and actors that contribute to strategies designed to promote health and prevent disease or injury (Altarum Institute, CDC et al. 2012, p. S73).” They established public health strategies as “the full array of actions undertaken by delivery system actors to promote health...including prevention programs and interventions; public health laws;...and instrumental activities...such as community health assessments, surveillance activities, strategic planning, and community mobilization efforts (Altarum Institute, CDC et al. 2012, p. s73).” Lastly, performance was defined as the effectiveness, efficiency, and equity of strategies employed. Arriving at a total of 72 research questions, the researchers grouped them into 4 domains and 17 thematic areas, which can be seen in Appendix 7.

### **5.3 Public Health Surveillance Evaluation**

As mentioned above, public health surveillance, while a tool for EBPH, is also a critical component of public health practice. Thus, PHSSR to evaluate public health interventions can yield useful information on its structure, governance, and performance. The research agenda for PHSSR places public health surveillance squarely in the middle of its ‘public health information and technology’ domain, with direct allusion within two of its thematic areas. The research questions

directly concerned with public health surveillance can be seen in Table 4 below (Altarum Institute, CDC et al. 2012).

**Table 4: PHSSR Research Questions Targeting Public Health Surveillance**

<u>Thematic Area</u>	<u>PHSSR Research Question</u>
<u>Capabilities to Assess and Monitor Health Outcomes</u>	How do the content, quality, and timelines of public health surveillance systems and informatics capabilities influence the effectiveness, efficiency, and outcomes of public health strategies delivered at local state, and national levels?
<u>Information and Communication Technologies</u>	<p>How do health information and communication technologies influence the effectiveness, efficiency, and outcomes of public health strategies delivered at local state and national levels (e.g., electronic health records, mobile health technologies, social media, electronic surveillance systems, geographic information systems, network analysis, predictive modeling)?</p> <p>How for EHR and PHR data systems as well as health information exchanges affect the content, quality, and <b>timeliness of public health surveillance systems</b>, and how do these changes in surveillance affect the quality of public health intervention strategies?</p>

Just as other subject matters within PHSSR, the evaluation of public health surveillance systems does not yet have a standardized methodology characterizing it, however it does have a well-developed set of guidelines that has been almost universally used, the most widely used being the CDC's *Updated Guidelines for Evaluating Public Health Surveillance Systems* and the WHO's *Communicable Disease Surveillance and Response Systems: Guide to Monitoring and Evaluation*. These two guidelines developed alongside the impetus for measuring public health system performance but drew on the same foundational texts that lead to the field of PHSSR. While both the evaluation guidelines ground their principles within the CDC's *Framework for Program Evaluation in Public Health*, the emphasis this framework places on program performance is a result of the 1988 IOM *The Future of Public Health* report laying the foundations of performance monitoring in the public health system (IOM 1997).

The stress placed on measuring performance in public health systems has also been placed on evaluating surveillance systems, with guidelines calling for public health practitioners to “gather credible evidence regarding the performance of the surveillance system (CDC 2001, p. 14)” and to “document the quality of the system and demonstrate any changes in its performance (WHO 2006, p. 31).”

Both the CDC’s *Updated Guidelines for Evaluating Public Health Surveillance Systems* and the WHO’s *Communicable Disease Surveillance and Response Systems: Guide to Monitoring and Evaluation* have been used extensively in the surveillance evaluation literature as a guide for focusing evaluations. While the CDC’s guidelines and the WHO’s guidelines differ in whether to approach core functions<sup>1</sup> and support functions<sup>2</sup> of a surveillance system, both highlight the importance of description of the surveillance system, including information on the disease, the purpose of the surveillance system, and the components of the system; and the resources used to operate the system. Furthermore, both place heavy emphasis on system attributes (as described by the CDC) and surveillance quality (as described by the WHO), in addition to how the evaluation should be conducted. As an example of the latter, a checklist of items that the CDC outlines in these guidelines can be found in Appendix 8. The system attributes and surveillance quality metrics emphasized in both the CDC’s and WHO’s guidelines include usefulness, simplicity, flexibility, completeness, validity, acceptability, sensitivity, specificity, predictive value positive, representativeness, timeliness, and stability (CDC 2001, WHO 2006). Not all these system attributes/surveillance quality metrics are emphasized by both guidelines. Table 5 below depicts what attribute/metric is present in each guideline.

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<sup>1</sup> Core Functions: These measure the processes and outputs of a surveillance system and include case detection, registration, confirmation, and reporting; data analysis/interpretation; epidemic preparedness; response and control; and feedback (WHO 2006, Sahal 2009).

<sup>2</sup> Supportive Functions: These facilitate implementation of core functions and include standards and guidelines, training, supervision, communication, resources, and coordination (WHO 2006, Sahal 2009).

**Table 5: System Attributes & Surveillance Quality Items Explicitly Listed in the CDC & WHO Evaluation Guidelines**

<b>System Attributes/Surveillance Quality Items</b>	<b>CDC</b>	<b>WHO</b>
<u>Usefulness</u>		✓
<u>Simplicity</u>	✓	✓
<u>Flexibility</u>	✓	✓
<u>Completeness</u>	✓	✓
<u>Validity</u>	✓	
<u>Acceptability</u>	✓	✓
<u>Sensitivity</u>	✓	✓
<u>Specificity</u>		✓
<u>Predictive Value Positive</u>	✓	✓
<u>Representativeness</u>	✓	✓
<u>Timeliness</u>	✓	✓
<u>Stability</u>	✓	

Analysis of surveillance system attributes provides invaluable information on the performance of a surveillance system. While all the attributes listed above have bearing on surveillance systems, their relative importance for evaluation will vary according to the public health event the surveillance system is tracking. Key subsets of surveillance systems are those dedicated for early detection of outbreaks. As surveillance systems are designed to better detect such increases in incidence, the necessity for information regarding usefulness and manners through which to support this function become highlighted. The CDC has published a framework for evaluating such surveillance systems as a supplement to the guidelines previously mentioned. This framework aims to arm public health officials with the means to achieve “timely...recognition and reporting [of disease cases and] patterns indicative of a possible outbreak early in its course (CDC 2004, p. 2).” Including two categories dedicated for analysis, this framework emphasizes outbreak detection, which includes timeliness and data validity; and system experience, which emphasizes usefulness, flexibility, acceptability, portability, stability, and costs.

Timeliness, as a system attribute, has been heavily emphasized in both the *CDC Updated Guidelines* and the more recent *CDC Framework* on evaluating surveillance for outbreak detection. Though not referenced in the guidelines, surveillance timeliness is also a targeted component in the agenda of PHSSR. At its core, timeliness reflects “the speed between steps in a public health surveillance system (CDC 2001, p. 22)” and can include stages from onset of exposure to initiation of public health intervention (CDC 2004). The rapidity of response required, however, varies according to the health event under surveillance and objectives of the system, in addition to the level of the public health system...and intended use of surveillance data (Jajosky and Groseclose 2004). For example, a disease with a short latency period will require a more timely surveillance system than a disease with a long latency period. Though timeliness is not a universal condition for all public health surveillance systems, it is for many (Wagner, Tsui et al. 2001). It is a key evaluation metric, and it reflects delay between response steps in a surveillance process and potential “rate limiting steps.” As such, timeliness has become a major focus of the surveillance evaluation literature.

### **5.3.1 Timeliness**

Despite its theoretical and practical importance, timeliness has not been measured in a standardized manner in the evaluation literature and is a relatively underdeveloped metric. Timeliness calculations range between loose measures of follow-up time ranges (Lin, Chen et al. 2012), estimates of proportion of cases followed up within pre-determined time ranges (Vogt, Spittle et al. 2006, Yoo, Park et al. 2009, Reijn, Swaan et al. 2011, Riera-Montes and Velicko 2011), and median and IQR estimates for surveillance steps (Vogt, Spittle et al. 2006, Trei and Carvelli 2008, Nicolay, Garvey et al. 2010, Riera-Montes and Velicko 2011, Jones, Le Hello et al. 2014). Other studies have calculated trends in timeliness, with one study focusing on changes in yearly mean timeliness over a 6-year time-span (Reijn, Swaan et al. 2011). However, very few studies have investigated the relationship between timeliness and factors of the disease and surveillance system.

Such studies that have investigated the relationship between timeliness and factors of the surveillance system and disease have focused on health system and surveillance system factors, such as clinical or lab source of reporting (Nicolay, Garvey et al. 2010, Jones, Le Hello et al. 2014) and level of clinic or lab from which reports are made (Akbari, Majdzadeh et al. 2013); geographical variables (Akbari, Majdzadeh et al. 2013, Jones, Le Hello et al. 2014, Rachas, Nakoune et al. 2014); and biological and epidemiological variables (Nicolay, Garvey et al. 2010, Akbari, Majdzadeh et al. 2013, Jones, Le Hello et al. 2014, Rachas, Nakoune et al. 2014). These studies have used both parametric and non-parametric methods of measuring timeliness. Those that used non-parametric methods, emphasized measures of median timeliness and have stratified estimates according to the independent variables (Nicolay, Garvey et al. 2010) or run non-parametric Chi-square tests (Akbari, Majdzadeh et al. 2013).

Amongst the four studies presented above, only two have used parametric models to investigate the timeliness of a surveillance system. One used a survival model (Rachas, Nakoune et al. 2014) and other constructed a model to compare cumulative distributions of time-spans between surveillance steps (Jones, Le Hello et al. 2014). These two studies investigated timeliness as an outcome of a surveillance system's factors, geographical factors, and biological & epidemiological factors of the health event. Knowledge of these factors can be useful for a country's public health department to find potential roadblocks to timely reporting and diffusion of health data, in addition to case follow-up.

This study will build on the use of parametric modeling found in the previous two studies to assess timeliness of Zanzibar's malaria case notification (MCN) malaria surveillance system. To our knowledge, no study has been conducted in Zanzibar to evaluate the timeliness of MCN. Furthermore, the only study in the literature that investigates the timeliness of a surveillance system in a malaria eliminating country was set in Iran (Akbari, Majdzadeh et al. 2013). Though the Iran

study does investigate factors that could affect surveillance timeliness, it does not use a parametric model. Furthermore, it does not investigate the crucial issue of trends in timeliness. As previous studies have mentioned, malaria elimination needs to be supported by a robust surveillance system that emphasizes the timely follow-up of index cases to investigate household (Ohrt, Roberts et al. 2014). This current study will fill a gap in the surveillance evaluation literature by focusing on a malaria eliminating country that has previously been excluded. Furthermore, by assessing if timeliness has improved since the inception of Zanzibar's MCN surveillance system, this study will be the first study to investigate if public health surveillance performance has improved to support malaria elimination. Furthermore, this study aims to bolster quantitative findings with qualitative investigation to gain a deeper understanding of the problems faced by stakeholders directly involved in the data collection and reporting steps. This is a critical element missing from the timeliness evaluation literature. A goal for better outcomes and timelier reporting and follow-up of cases can be achieved through "eliminating the need for conscious effort in reporting (Foldy 2004, p. 5)." As a result, understanding what challenges personnel face during reporting and data collection steps in the surveillance system will be important for a holistic understanding of the timeliness of a surveillance system. This study will address this black box in the timeliness evaluation literature by conducting focus group discussions with key surveillance personnel.

By investigating trends in timeliness and the interaction of stakeholders responsible for producing data with MCN, this study's findings could identify roadblocks and key points of leverage to strengthen MCN as a supportive pillar for malaria elimination in Zanzibar.

## 6.0 Methods

This study conducted a performance evaluation of Zanzibar's Malaria Case Notification (MCN) surveillance system. The design of the study was guided by the need to strengthen malaria surveillance in Zanzibar, so as to better respond to rises in localized cases and meet its elimination goals. This study grounds its focus on timeliness from the CDC's *Updated Guidelines for Evaluating Public Health Surveillance Systems*. This evaluation specifically focused on MCN's timeliness in addition to stakeholder interaction with MCN. The two aims of the study are further subdivided into the following objectives:

1. Evaluation of MCN's Timeliness: This study component assessed timeliness, hereafter called response time, to understand how effectively MCN is performing in order to meet both its programmatic goals and Zanzibar's broader goal of malaria elimination. There are three sub-goals in this component that sought to answer the questions:
  - a. Has response time to reported cases improved since MCN inception in 2012?
  - b. Is response time associated with work load (the number of reported cases and household members)
  - c. Does the association of response time with time and workload vary by district?
  
2. Assessment of stakeholder interaction with MCN: This study component assessed how DMSOs, those responsible for following up on cases at both the health facility and household levels, interact with MCN. As they alone represent the RACD component of MCN they are well positioned to provide insight on challenges that MCN faces. Specifically, this component addressed DMSO interaction at three stages:
  - a. Health Facility Level
  - b. Travel to Household

### c. Household Level & Household Member Testing

The two components of the study were conducted using a mixed methods approach. A quantitative analysis was used to evaluate response time in MCN and a qualitative analysis was used to assess stakeholder interaction with MCN. The quantitative component used a time series regression and the qualitative component used a survey, with both closed and open-ended questions, in addition to follow-up focus groups to probe emerging themes.

## **6.1 Timeliness Analysis**

The quantitative analysis of timeliness comprises the main focus of the study. Data were obtained with permission from RTI and ZAMEP, with all case records from October 5, 2012 to July 31<sup>st</sup>, 2014 being collected. Data within the dataset exist on the individual patient level, with patients being de-identified with a case ID #. Each case ID # has corresponding time-stamps for every step of the surveillance system (the USSD notification, case notification, health facility follow-up, health facility follow-up, and household member testing) in addition to information on the patient (age, gender, etc.), health facility, and household (beds, bed nets, etc.). A full table depicting the information available can be seen in Appendix 5. These time stamps have been used to test the hypotheses below.

*Hypothesis 1:* Response Time has improved since the inception of the MCN surveillance system

*Hypothesis 2:* Response time is positively associated with workload

*Hypothesis 3a & 3b:* The association of response time with time and workload does vary by district

Quantitative analysis was conducted using both MS Excel & STATA. MS Excel was used to build and manipulate the data set and OpenRefine was used to clean the data. Once constructed, the data set was transferred to STATA version 13 for conducting the analysis.

### 6.1.1 Data Preparation

As the primary outcome of interest was response time of MCN, the time-stamps associated with surveillance system steps were the primary variables of interest. Each step in the surveillance system had two time-stamps associated with it: --“date opened” and “date saved.” Response time in this study was defined as the time between when a case was reported to the system and when all household members of that case were followed up on. As a result, the two time-stamps used to measure response time were the USSD Notification time-stamp and the last household member follow-up completion time-stamp. The difference between these two time-stamps should provide a clear measure of response time, which will be measured in days. Due to loss to follow-up, not all cases had time-stamps for both events. Each case also had a variable termed “saved by” which represented the DMSO assigned to the case. The data structure is depicted below in Table 6.

**Table 6: Data Structure of Reported Cases & Time-stamps in MCN**

Case ID	USSD Notification	Last Household Timestamp	DMSO
<u>10071</u>	10/11/12 08:58:34	10/11/12 13:07:34	777477900
<u>10072</u>	10/11/12 09:49:38	10/31/12 12:53:04	773507191
<u>10073</u>	10/11/12 10:30:49	10/23/12 14:19:57	773513887
<u>10074</u>	10/11/12 12:01:05	.	.

Time-stamp formatting changed within Coconut Surveillance mid-2013, making subtraction between time-stamps impossible. Time-Stamp formatting was universalized in OpenRefine v. 2.0 using its ‘chomp’ feature to remove extraneous characters and its ‘data transform’ feature to create a consistent date/time formatting. Cleaned data were exported into MS Excel. Once in Excel, the “time” variable, the primary explanatory variable of interest, was constructed. Using the first USSD

notification sent to MCN as a proxy, a discrete, continuous variable was created for time. Time was measured as days in the MCN system. As multiple cases were reported in one day, a specific number of days in the system did repeat in the data. An example these data of this can be seen in Table 7 below.

**Table 7: Time (Days) & Repeated Case Reporting per Day**

<u>Time (Days)</u>	<u>USSD Notification</u>
<u>1</u>	<u>10/5/12 10:41:50</u>
<u>4</u>	<u>10/8/12 11:50:52</u>
<u>4</u>	<u>10/8/12 23:46:17</u>
<u>4</u>	<u>10/8/12 23:49:20</u>
<u>4</u>	<u>10/8/12 23:51:22</u>
<u>4</u>	<u>10/8/12 23:55:10</u>
<u>4</u>	<u>10/8/12 23:59:10</u>
<u>5</u>	<u>10/9/12 09:17:34</u>
<u>5</u>	<u>10/9/12 16:20:11</u>
<u>5</u>	<u>10/9/12 16:22:16</u>

Before the difference between USSD Notifications and the Last Household Timestamp was taken, all data were exported in to STATA. Data were formatted into STATA data/time formats and the difference in time-stamps was taken. The resulting output was formatted as a STATA-readable time difference but was un-readable in terms of real-world time. The output was then transformed into hours and then days. Once in the day format, the data were then ready for modeling. Additional variables of interest were:

- Case Count: This variable was a crucial control variable and was used to capture the workload at the front end of the surveillance system. It was hypothesized that as the number of reported cases increased, the response time would also increase. This variable was constructed by counting the number of cases reported per day per district.
- Household Size: This was another crucial control variable and was used to capture the workload at the back end of the surveillance system. When DMSOs follow-up on cases, they

need to collect full information on the household, including all household members. As mentioned above response time was defined as the time-span between when a case was reported and all household members were followed-up on. Accordingly, it was hypothesized that as the size of household increases the response time would also increase.

\*\* Case Count and Household Size are collectively referred to as workload.

- District: This variable represents the district a case was reported in. It is unlikely that response time is the same across all districts in Zanzibar. For example, some districts in Zanzibar may be more urban than others, which could change how quickly a follow-up is conducted. Furthermore, various factors within the district could affect the association of response time with time and workload, e.g. infrastructure development, community behavior, etc. Accordingly, it is hypothesized that the association of response time with time and workload will vary by district.

### **6.1.2 Modeling Aggregate Trends in Response Time**

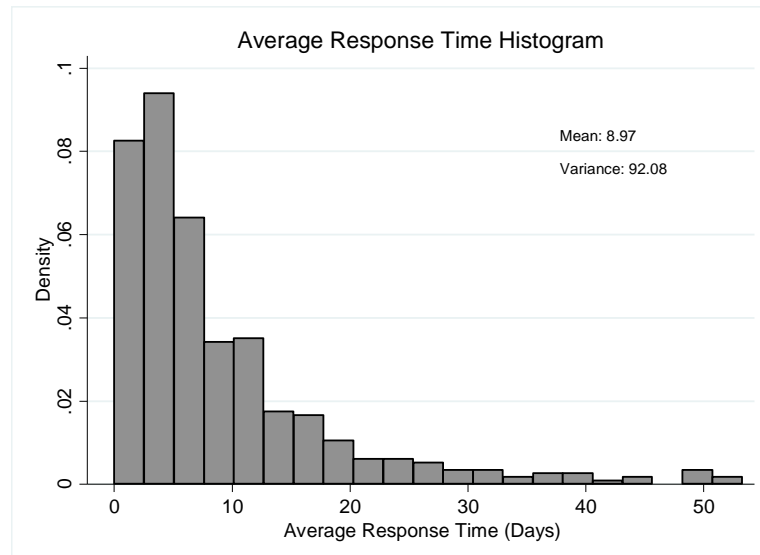
At the core of this quantitative analysis is a time series regression, as the primary aim is to understand how response time (days) has changed over time (days). The data used for analysis covers surveillance data between October 5<sup>th</sup>, 2012 and July 31<sup>st</sup>, 2013, for a total of 634 days in the time series. The data were then aggregated at the day level better observe trends in response time. To do so, the response time for each case was averaged for each day to provide a measure for *average daily response time*. This variable provides the average daily response time in MCN for all of Zanzibar, with no stratification by any variable. At this level, the only variable of interest still discernable was the number of reported cases per day.

Understanding how average daily response time changes over time is difficult in time series, as observations are not independent. Those closer together in time are likely to be more correlated with one another than those farther apart (Zeger, Irizarry et al. 2006, Bhaskaran, Gasparrini et al. 2013). As a result, the response time data were analyzed for both temporal autocorrelation and periodicity and parameters were developed to control for both.

Temporal autocorrelation is traditionally controlled for by using lag-terms of the outcome variable, as done in time-series analysis techniques such as Box-Jenkins or Autoregressive Integrated Moving Average (ARIMA). Autocorrelation function (ACF) plots were generated to determine the most significant average daily response time lag-terms. While these were noted with the assumption that autocorrelation was intrinsic to the outcome of response time, the possibility of the number of cases as a cause of autocorrelation was also investigated. Recent research has indicated that autocorrelation may not always be intrinsic to the outcome variable, but a product of autocorrelation in explanatory variables (Bhaskaran, Gasparrini et al. 2013).

Periodicity is often seen in epidemiological data, especially for seasonal diseases. Malaria transmission is characterized by seasonality and coincides with rainy seasons (Fisman 2007). As malaria transmission is characterized by periodic behavior, it is expected that response time will follow a periodic trend as well. Periodicity of response time should follow the same trend as periodicity of malaria prevalence. The outcome of interest is the linear association of response time with time. As such, periodicity needs to be controlled as well. Periodicity in the data was controlled for with the use of Fourier terms, sine and cosine pairs of variables. Multiple harmonics of the Fourier term were utilized to allow for flexibility in the model.

The outcome variable in this model is a count of days, and the one regression method for modeling such data is a Poisson regression. At a first glance, the histogram of the average daily response time data, shown below in Figure 16, indicates a Poisson distribution.



**Figure 14: Histogram of Average Daily Response Time**

However, the distribution of *average daily response time* data violates the assumption that the mean and variance are equal. As shown in the figure above, the variance is significantly larger than the mean, suggesting over-dispersion of the outcome variable. As the underlying assumptions of a Poisson distribution were violated, a negative binomial regression was used. The best model was estimated by conducting forward stepwise estimation, using likelihood ratio tests as each variable was added.

### 6.1.3 Modeling Case-Level Trends in Response Time

In addition to investigating the association between aggregate response time and time, the relationship between response time per individual case and time was also assessed. This used data

structured at the case level, for a total of 4774 reported cases. Case level data had multiple additional variables linked to each reported case, allowing for additional details to be considered when modeling response time. The outcome variable here is the **average response time per case**, which will again be measured in days.

The additional variables of interest include: number of reported cases, household size, and district the case was reported in.

Unlike the data used to model average response time per day, which only had one observation per day, the case level data had repeated observations per day. As a result, the case response data are not a true time series, and methods used in the daily model, such as lag-terms, could not be used. Regardless, *average response time per case* data will likely still be characterized by periodicity. Furthermore, there is still likely to be autocorrelation in the data. This is the product of how data are generated in MCN. Recall in chapter 4 that individual DMSOs follow-up on cases. It is very likely then that response times to cases will be more correlated to each other if the same DMSO responded to them. As a result, the response time per case is possibly cluster correlated on the DMSO.

The best approach for analyzing clustered data is to use a random effects model that explicitly allows for clustering. While a random effects negative binomial model could have been used, it did not fit the data well. As a result, the data were modeled with a general estimating equation (GEE). A GEE was preferred to a random effects model as clustering needed to be treated a nuisance variable. The GEE model clustered by DMSO; used a negative binomial family to define the distribution of case response time data; and used an exchangeable correlation structure, as it assumes that the correlation between a pair of observations in the same cluster is the same for all pairs in each cluster. Model estimation for these two models could not use likelihood ratios as GEE

is based on quasi-likelihood theory. As a result, a backwards-stepwise method was used to estimate the best model, using a critical p-value of 0.01. The initial model used for the backwards-stepwise method included variables for time, district, Fourier-terms (to account for periodicity), reported cases, and the number of household members.

#### **6.1.4 Modeling Association of Response Time by District with Workload**

The response time per case models for each district were constructed in a similar manner as the response time per case model for all of Zanzibar. They were all constructed using a backwards-stepwise model estimation process, using a critical p-value of 0.01. The initial model included variables for time, district, Fourier-terms (to account for periodicity), reported cases, and the number of household members. At the district level the clustering by DMSOs was minimized. GEE models were initially used to construct models. However, they would not fit the data well and as a result they were exchanged for regular negative binomial regressions.

### **6.2 Stakeholder Analysis**

This section focused on one group of stakeholders who are directly involved in the data collection and reporting process of the MCN surveillance system, the district malaria surveillance officers (DMSOs). These individuals were targeted as the intended focus of study was on the challenges encountered during the data collection process and reporting steps. DMSOs directly contribute to each data collection and reporting step within the MCN surveillance system and solely contribute to RACD in MCN. As such, they can offer tremendous insight on MCN.

Within the two islands of Zanzibar, there are 10 districts and two DMSOs per district. Each of these 20 DMSOs was sent an initial survey with both closed and open-ended questions. Emergent themes in responses were explored more deeply through follow-up focus group discussions. DMSOs

located on the island of Unguja were approached during their weekly meeting at the ZAMEP office in Zanzibar City. After obtaining their consent to participate in the study, each DMSO was provided a hard copy of the survey in Kiswahili and was requested to complete it and return it at their next weekly meeting. Surveys were analyzed and focus groups were scheduled a week after the surveys were returned. DMSOs in Pemba were recruited through the field manager at the ZAMEP office in Pemba and surveys were emailed to him. Just as for the DMSOs in Unguja, DMSOs in Pemba were provided the surveys at their weekly meeting and were requested to return them the following week. A follow-up focus group was scheduled a week after surveys were returned.

### **6.2.1 Survey Methods**

The surveys, presented in Appendix 9, provided to DMSOs in Unguja and Pemba covered the same global themes and were identical in nature. The topics addressed in the survey were: transportation, completeness and accuracy of data in malaria case registers (MCRs) at health facilities, the follow-up process and household member testing, DMSO proactiveness and resilience, and technical problems. These specific issues were investigated as they traced the path DMSOs took when responding to cases. As DMSOs often have to get themselves to health facilities and index case household, transportation can be a crucial issue. The data recorded in MCRs, especially in relation to patient contact and location information are used by DMSOs for the follow-up process. As a result, it was important to understand if these data were not recorded correctly. Locating the household and testing household members is an important step in the RACD component of MCN. Thus, understanding obstacles encountered is critical. Assessing how DMSOs deal with these obstacles is important for understanding not only if it is possible but also to identify points of leverage to strengthen MCN. Lastly, technical problems were assessed as technology is used heavily by MCN.

Surveys were translated into Kiswahili with the aid of ZAMEP office staff, and responses were back translated into English with the help of the same individual who initially translated the surveys. Analysis of surveys included summary statistics of the closed ended questions and theme analysis of the open-ended questions.

### **6.2.2 Focus Groups Methods**

As mentioned above, focus groups were scheduled a week after surveys were returned. Consent for participation was received at the beginning of both focus groups in addition to consent for recording of the focus groups. The emergent themes discovered through survey response analysis were outlined and used to develop global questions and anticipated probing questions. These were provided to the moderator of both focus groups beforehand. The focus group discussion in Unguja was moderated by the individual who translated the surveys, whereas the focus group discussion in Pemba was moderated by the field manager at the ZAMEP office. A separate translator was used in both instances to translate the discussion in real time. Even though both focus groups were recorded, in depth notes were taken. Due to the poor quality of the recordings, the notes on the focus group discussions were used as the material for the qualitative analysis.

## 7.0 Results

This study conducted a performance evaluation of Zanzibar's MCN malaria surveillance system, emphasizing timeliness and stakeholder interaction with MCN. This chapter will first present findings obtained from the evaluation, first starting with the timeliness analysis results and finishing with the stakeholder analysis results.

### 7.1 Timeliness Analysis

Two models were used to estimate the changes in response time to USSD notifications in Zanzibar: a daily average response time model and a case response time model. Both models controlled the periodicity in response time with the addition of Fourier terms. Autocorrelation was more easily controlled in the daily average response time model. As the daily average response time model is true time series model, lag terms for response time were added. Though the case level response time data possibly had autocorrelation, lag terms could not be added. As data at this level had repeated observations on the same day, it was not a true time series. However, as the same DMSO could collect multiple cases, the data were considered to be cluster-correlated. This clustering was successfully controlled for using a GEE model. The final models used to analyze changes in response time over time were the following:

#### Equation 2: Daily Average Response Time

$$\begin{aligned} \text{Response Time} = & \beta_0 + \beta_1 t + \beta_2 \text{Response}_{t-1} + \beta_3 \text{Response}_{t-2} + \beta_4 \sin\left(\frac{2\pi t}{365}\right) + \\ & \beta_5 \cos\left(\frac{2\pi t}{365}\right) + \beta_6 \sin\left(\frac{4\pi t}{365}\right) + \beta_6 \cos\left(\frac{4\pi t}{365}\right) \end{aligned}$$

#### Equation 3: Case Level Response Time

$$\text{Response time} = \beta_0 + \beta_1 t + \beta_3 \text{District} + \beta_4 \sin\left(\frac{2\pi t}{365}\right) + \beta_5 \cos\left(\frac{2\pi t}{365}\right) + \beta_6 \sin\left(\frac{4\pi t}{365}\right)$$

## **7.1.1 Daily Average Response Time Model**

### **7.1.1.1 Model Construction**

Before variables were selected to model response time at the daily aggregate level, the raw data were evaluated. Plotting average daily response time against time, from October 5<sup>th</sup>, 2012 to July 31<sup>st</sup>, 2013, the first two things noticed were an unusually large peak occurring on November 5<sup>th</sup>, 2012 and a negative average response time on March 10<sup>th</sup>, 2014. This graph can be seen in Appendix 10. These aberrations were removed before model construction i.e. only data after the peak on November 5<sup>th</sup> 2012 and only response time observations with a value above zero were included.

The observations before November 5<sup>th</sup> were removed to clean the data of the peak and because October to November 2012 was the first month in which MCN was operating. It is unlikely this peak was caused by an actual delay in follow-up but was rather a data storage issue. During this time health facilities and DMSOs were still getting introduced to MCN. Furthermore, it is likely that technological errors were frequent in the first month. As a result, response time during this first month may not be an adequate representation of MCN.

Response time observations below zero days were assumed to be data storage errors, but it is less clear why observations with a value of zero occurred. It is likely that these were results of data storage errors. Another reason for this to occur could be if a household member of a previously reported index case is tested positive for malaria at a health facility at later date. Since the household member was already captured in the previous index case, they were automatically considered complete in MCN. Since the outcome of interest is the time between health facility reporting of a case and the last household member follow-up, observations with a value of zero were excluded.

These data were re-plotted against time and can be seen in Figure 17 on the next page. A moving average curve was produced and is displayed on the graph as well as highlighted regions for when the peak malaria transmission seasons occurred in both 2013 and 2014.

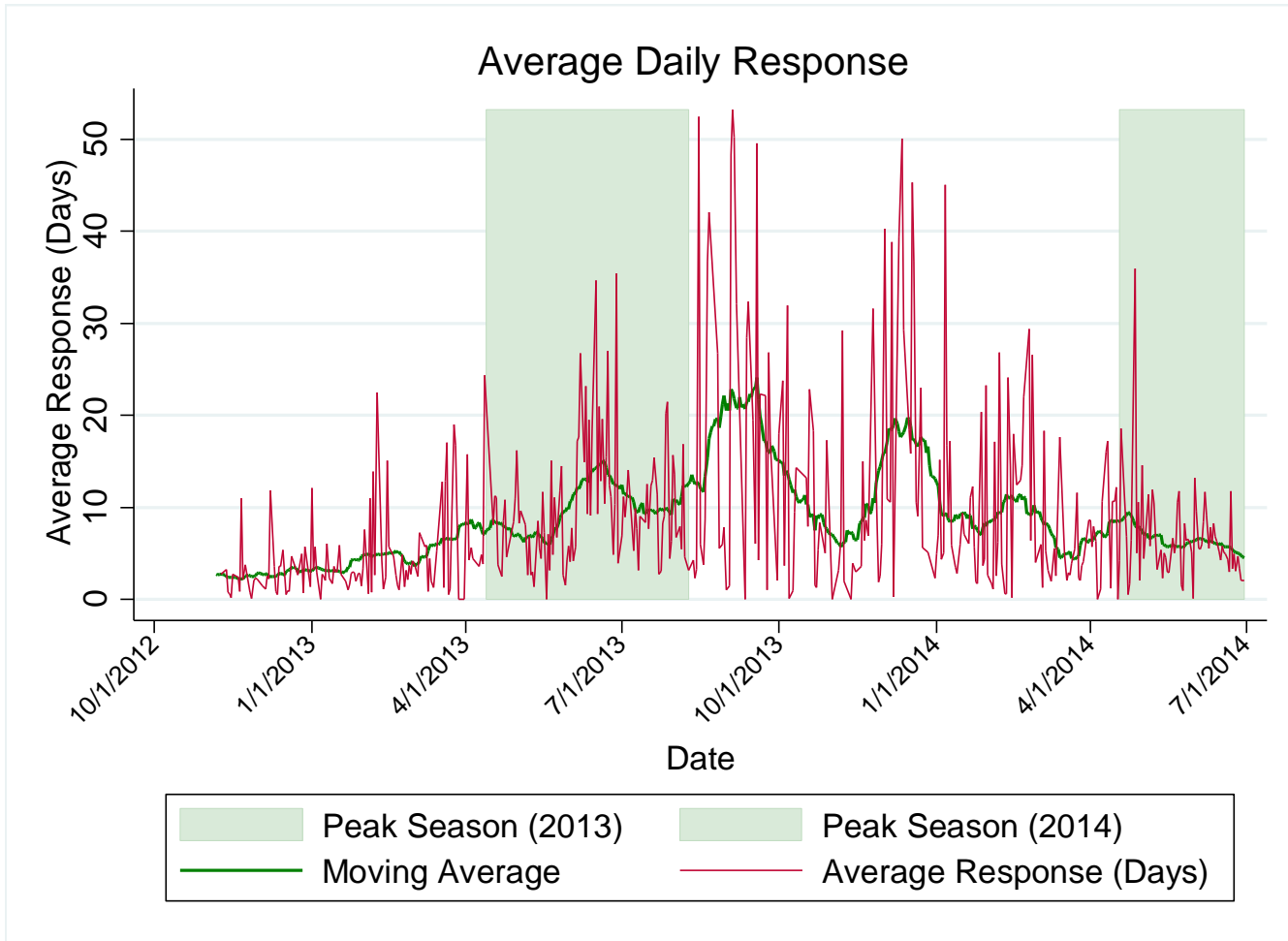
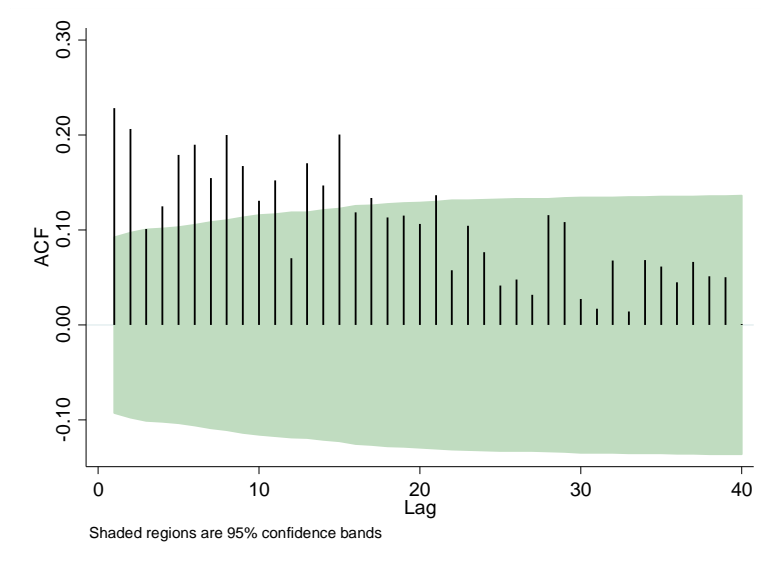


Figure 15: Average Daily Response Time Raw Data

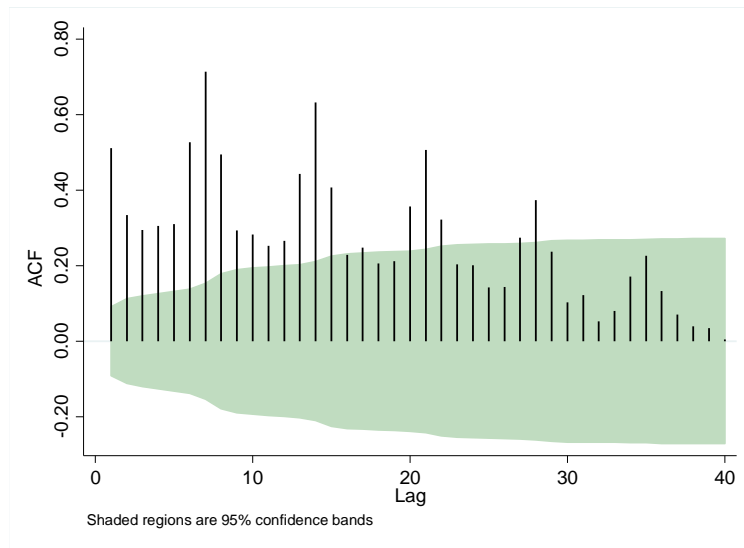
Figure 17 indicates that there is some periodicity to the average response time per day, a pattern that is made more apparent by the moving average curve. While periodicity was expected to be annual, with two clean peaks during peak malaria transmission seasons, the periodicity in response time displays a more complex waveform. Additionally, the overall trend appears to increase and then decrease over time, maintaining a more or less stationary process. It is important to note, for the purpose of this investigation, that while response time at the end of the observed data appears to decrease to the same level of response time at the beginning of the observed data, this occurs at very different transmission levels of malaria. At the beginning of the response time data, in November, malaria is at a low transmission season and at the end of the response time data, in July, malaria is in a high transmission season. It is also important to note that there appears to be a peak in average response time during the peak malaria transmission season in 2013, and a much smaller peak in average response time during the peak malaria transmission season in 2014. There are also noticeable peaks in response time at times of the year that are not peak malaria transmission seasons

As the daily average response time data are a time-series, autocorrelation is a potential confounder when determining long-term trends. To assess the autocorrelation in the response time data, an ACF was constructed and can be seen below in Figure 18. An ACF illustrates the linear dependence between two points in time: time point  $x_t$  and a lag order time point  $x_{t-h}$ . The ACF was created by excluding all observed response times before November 5<sup>th</sup>, 2012, the time point where the spike in response time occurred, and dropping the negative response time observation.



**Figure 16: ACF of Response Time**

According to the ACF there is linear correlation between time points, with the most statistically significant linear correlation occurring between  $t$  and  $t-1$ ,  $t-2$ ,  $t-5$ ,  $t-6$ , and  $t-8$ . While using lag-terms alone could account for autocorrelation, research has indicated that it can also be a product of autocorrelation in an explanatory variable (Bhaskaran, Gasparrini et al. 2013). The only explanatory variable available in data set at the aggregate day level is the number of reported cases. Thus, it became important to investigate first the correlation between the number of reported cases and response time and the autocorrelation within the number of reported cases. A correlation matrix, after excluding data before November 5<sup>th</sup>, 2012 and negative observed response time, indicated that case count and response time had small positive relationship with a coefficient of 0.041. While this is small, it did not exclude the possibility that reported cases cause autocorrelation in response time. An ACF of reported cases, seen in Figure 19 indicates that there is autocorrelation in reported cases.



**Figure 17: ACF of Reported Cases**

The ACF in Figure 19 indicates there are highly statistically significant linear correlations between cases reported on time  $t$  and time  $t-1$  and  $t-7$ . Furthermore, there is an interesting periodicity in the autocorrelation function, with a peak occurring every 7 days. This trend, however, appears to diminish as the peak intensities decrease. This evidence supports the use of reported case count as an indicator of the autocorrelation in addition to periodicity in response time.

While it seems that the number of reported cases can control autocorrelation and possibly periodicity of average daily response time, it is important to assess response time for other indications of periodicity. In order to do so, the trends in the case count and average response time were displayed in an overlay chart (Figure 20). The overlay chart indicates that some periodicity in the average response time is associated by periodicity in reported cases. However, there are additional peaks in the average daily response time raw data that occur at different times than do peaks in the reported cases raw data, indicating that response time has periodicity independent of the number of reported cases.

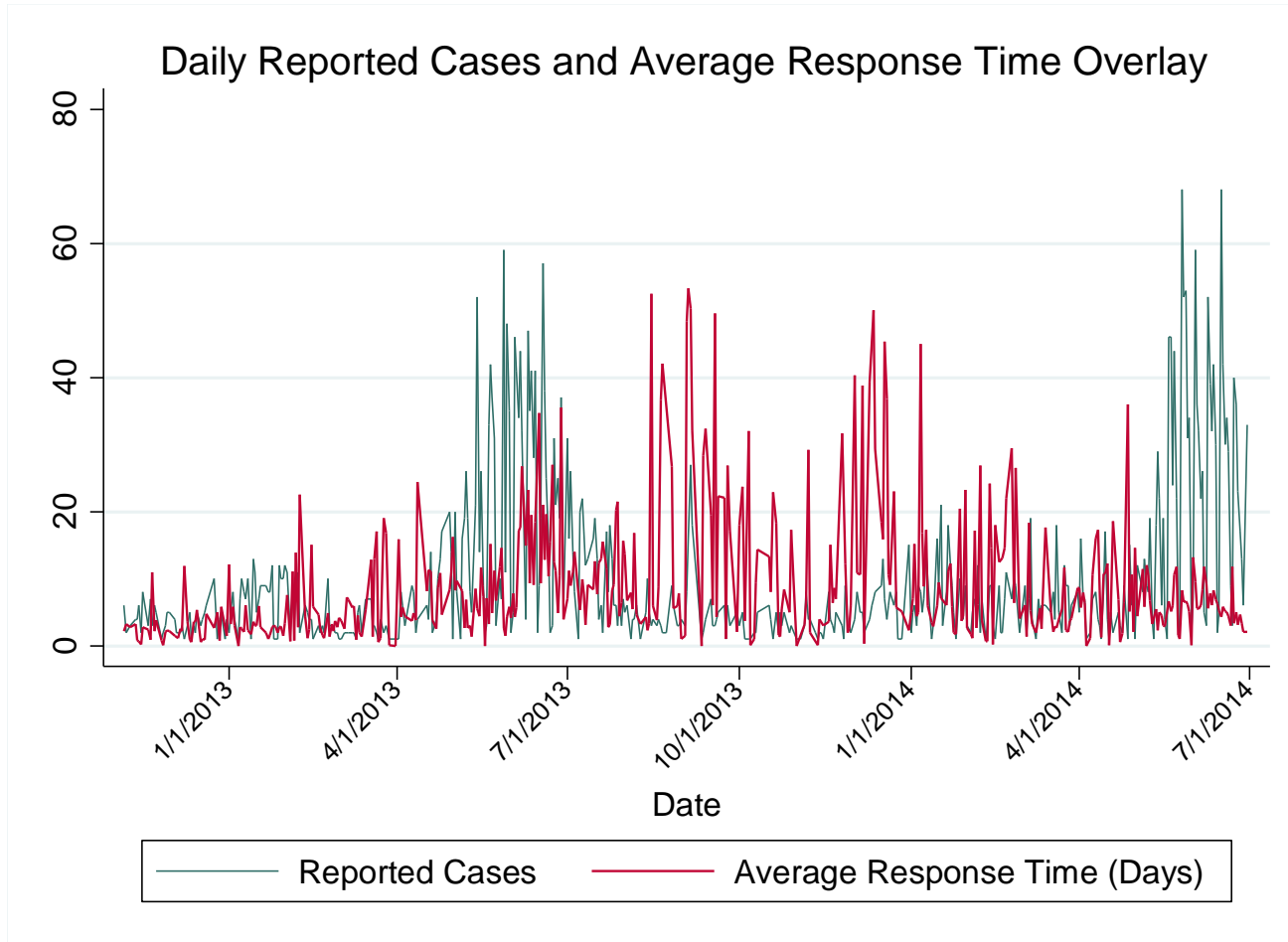


Figure 18: Overlay Chart of Daily Reported Cases and Average Response Time

At this stage, it was important to check whether the number of reported cases or lag-terms of daily average response time was a better predictor of response time. Using a negative binomial regression on the baseline model below, likelihood ratio tests were performed for both reported cases and lag-terms.

**Equation 4: Baseline Model**

$$\text{Response Time} = \beta_0 + \beta_1 t$$

Likelihood ratio tests indicated that the addition of reported cases did not yield a better model. However, the addition of lag terms  $t-1$  and  $t-2$  of average daily response time produced a better model. These two terms were added as they had the most statistically significant linear relation to response time at  $t_0$ , as seen in Figure 18. As a reference, the results from likelihood ratio tests can be seen in Appendix 11.

While the lag terms can control for autocorrelation, they may not control for periodicity. As the goal of this investigation is to assess the long-term trends in response time, it will be important to control for periodicity observed in the raw response time data. Following the direction of Bhaskaran, Gasparrini et al. (2013) periodicity was controlled with the use of Fourier terms. As periodicity of response time did not seem to follow a clean seasonal cycle, multiple harmonics were used to allow the model to follow a waveform of a more complex nature. This model drew from the Serfling model, which uses both a linear time terms and Fourier time terms. The model used a linear time variable and Fourier terms with both a fundamental harmonic and its second harmonic. As the malaria case data exist on the daily level, Fourier terms used a period of one year. Both harmonics were added based on results from likelihood ratio tests. Similar Fourier terms were used with a week as its period, due to the weekly periodicity observed in the ACF of reported cases. However, likelihood ratio tests determined that these terms did not yield a better model.

**Equation 5: Fundamental Harmonics for Fourier Terms Used in the Model**

$$\sin\left(\frac{2\pi t}{365}\right) \qquad \cos\left(\frac{2\pi t}{365}\right)$$

**7.1.1.2 Model Finalization and Estimates**

The final model to estimate how **average daily response time** changed over time, arrived at after the addition of lag-terms, the fundamental harmonic, and second harmonic is the following:

**Equation 6: Final Daily Average Response Time Model**

$$\begin{aligned} \text{Response Time} &= \beta_0 + \beta_1 t + \beta_2 \text{Response}_{t-1} + \beta_3 \text{Response}_{t-2} \\ &+ \beta_4 \sin\left(\frac{2\pi t}{365}\right) + \beta_5 \cos\left(\frac{2\pi t}{365}\right) + \beta_6 \sin\left(\frac{4\pi t}{365}\right) + \beta_7 \cos\left(\frac{4\pi t}{365}\right) \end{aligned}$$

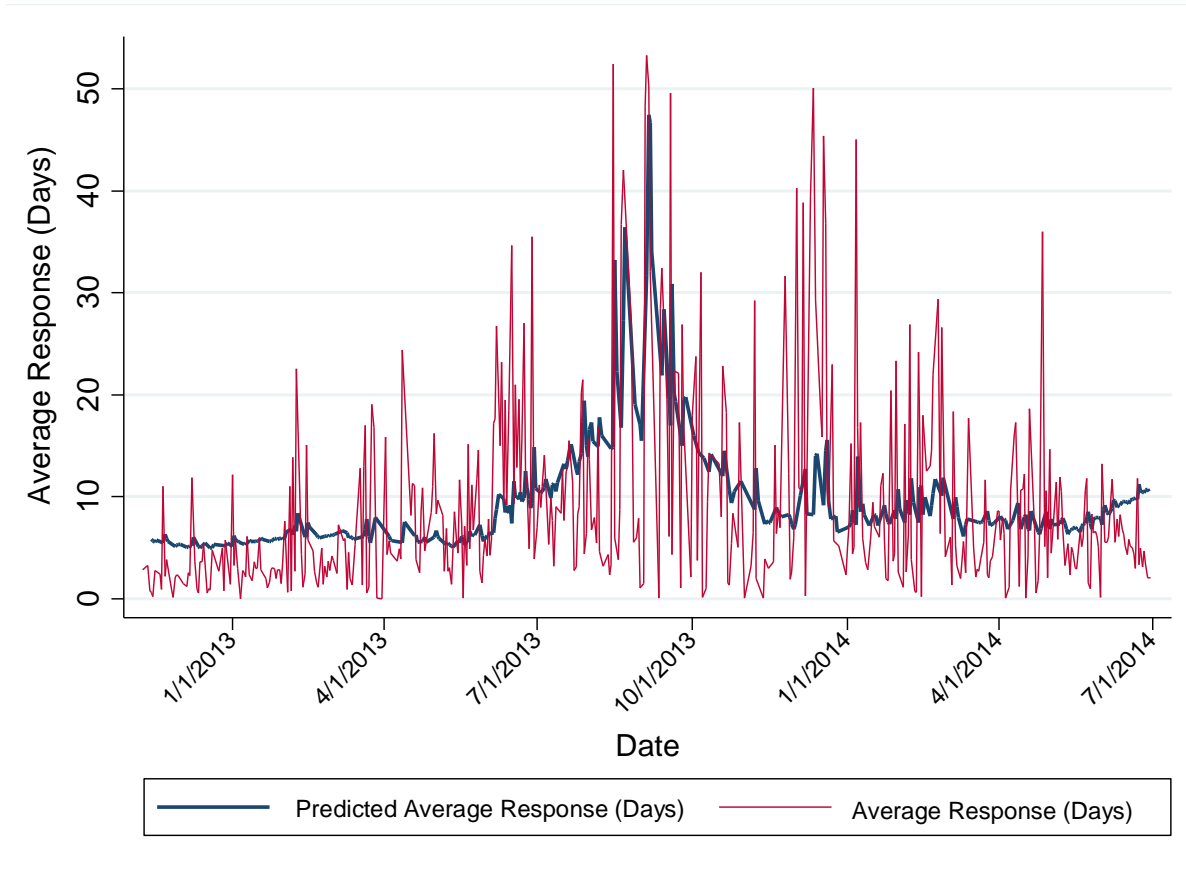
A negative binomial regression was run and results were exponentiated to convert them into incidence rate ratios. Since the data were still correlated by DMSOs in the daily response time model, the regression was re-run with robust standard errors, using the Huber-White Sandwich Estimator (Freedman 2006). Table 8 on the next page provides the coefficient, standard errors, and p-values for each variable for both the regressions. As can be seen, the coefficients in the model do not change. While p-values do become larger, the statistical significance of almost all parameter estimates does not change. The only variable that has a p-value change enough to make its significance level change is that of the sine term of the fundamental harmonic. For ease of interpretation, this has been highlighted in Table 8 below. As the model was robust to using robust standard errors, it was determined to be valid for drawing estimates.

**Table 8: Daily Average Response Time Model Estimates**

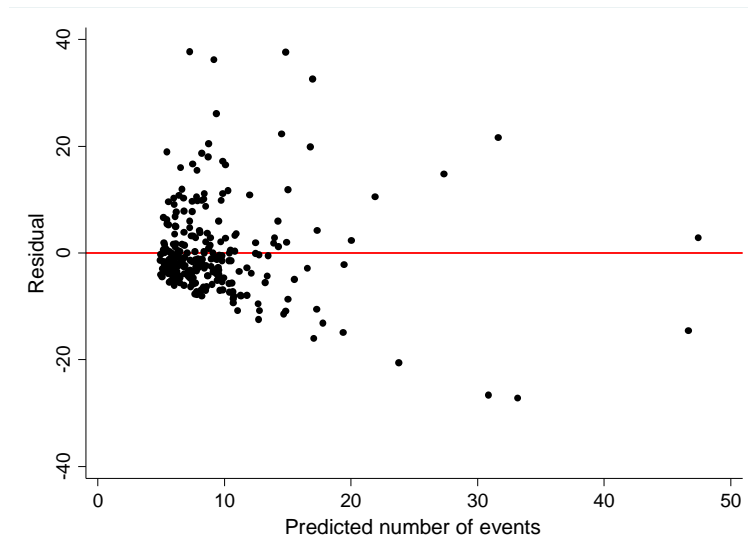
Daily Response Model with normal standard errors								
	Time (Days)	Response Lag 1	Response Lag 2	Sin (Time)	Cos (Time)	Sin (Time) 2nd Harmonic	Cos (Time) 2nd Harmonic	Constant
Estimate (IRR)	1.000682	1.016259	1.007043	0.817555	1.409789	0.7817489	1.048897	6.054345
Standard Error	0.000299	0.005714	0.0050091	0.0577059	0.1304379	0.0587074	0.0799693	0.785771
p-value	0.022**	0.004***	0.158	0.004***	0.000***	0.001***	0.531	0.000***
* = significant at 0.1 level ** = significant at 0.05 level *** = significant at 0.01 level								
Daily Response Model with robust standard errors								
	Time (Days)	Response Lag 1	Response Lag 2	Sin (Time)	Cos (Time)	Sin (Time) 2nd Harmonic	Cos (Time) 2nd Harmonic	Constant
Estimate (IRR)	1.000682	1.016259	1.007043	0.817555	1.409789	0.7817489	1.048897	6.054345
Standard Error	0.000318	0.0062727	0.0078037	0.0714002	0.1459266	0.0671134	0.089194	0.824403
p-value	0.032**	0.009***	0.365	0.021**	0.001***	0.004***	0.575	0.000***
* = significant at 0.1 level ** = significant at 0.05 level *** = significant at 0.01 level								

The sine and cosine variables in the model above are essentially nuisance variables and do not need to be interpreted directly. However, they are fundamental to the model and capture seasonality and other periodic trends. According to the results, response time following up a case to completion has increased over time. The incidence rate ratio indicates by how much percent response time increases each additional day into the surveillance system. With an IRR of 1.000682, this means that response time has increased by 0.068% per day when controlling for periodicity of response time and autocorrelation of response time. The first lag-term, while controlling for autocorrelation, provides important information about the surveillance system. If the average response time for cases reported yesterday increases by 1 day, this means that the average response time for cases reported today increases by 1.63%. Using the model estimates, daily response time has increased from an average 6.05 days to 9.13 days. However, note that the data start from a low malaria transmission season in late 2012 and ends in the middle of the peak malaria transmission in 2014. While the model estimates indicate that response time has increased, it does not necessarily mean that MCN is performing less effectively.

This model was used to construct a predicted estimate plot and was overlaid against the observed response time. This graph can be seen in Figure 21 on the next page. The predicted model appears to follow the periodicity of the observed data relatively well. However, the large peak in the center of the observed data also seems to pull the predicted estimates upwards. This indicates that the model may be over-estimating response time, a theory that was confirmed by a residual v fitted plot, seen in Figure 22.



**Figure 19: Observed and Predicted Daily Average Response Time**

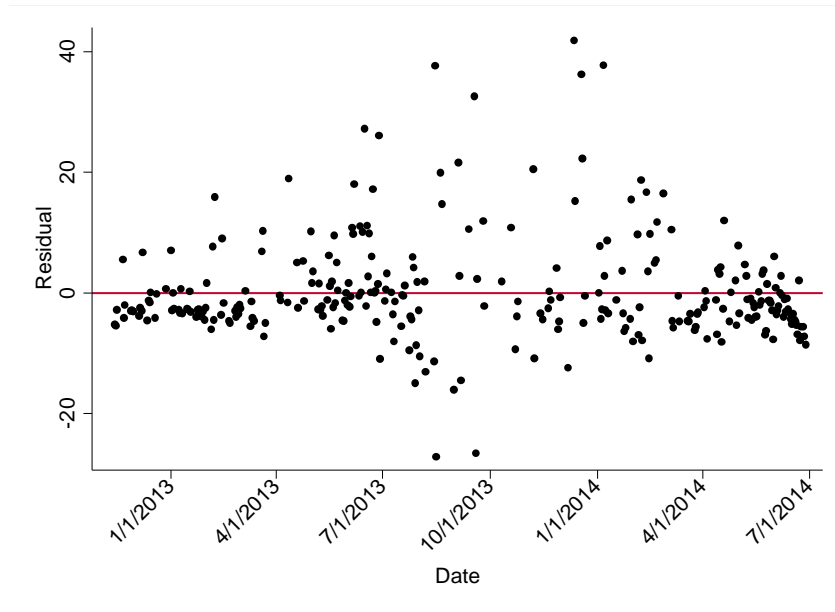


**Figure 20: Residual v Fitted Plot of Daily Average Response Model**

This figure also displays heteroscedasticity in the residuals; the downward trend in the plot indicates that the higher the estimate the more overestimation is occurring. This is likely due to the fixed nature of the Fourier terms. While adding harmonics allowed for more flexibility, the presence of sine and cosine terms forces a fixed sinusoidal pattern into the model. It appears that by adding sine and cosine terms the model estimates are pulled upwards by higher observed values despite the bulk of the density of observed values being much lower.

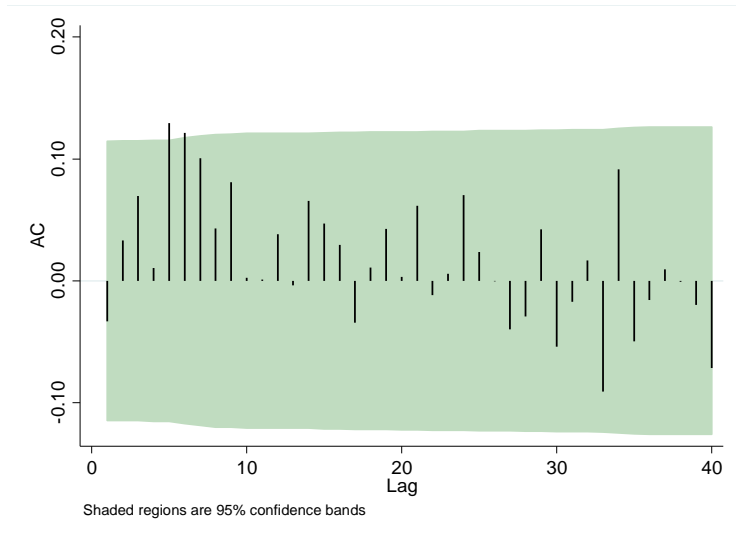
While the residual analysis above indicates that the model may not be the best fit for the observed data, two more key residual plots should be examined: a residual variation with time plot and a residual autocorrelation plot. These two checks are an essential component of time series analysis and will indicate if additional time-varying factors were excluded. The first plot of residual variation time can be seen below in Figure 23. For the most part, the residuals appear to be time invariant. However, just as a peak occurred in the raw data towards the middle of the time series, another peak was seen in a similar area in the residual-time plot, a pattern noticed on both sides of the referent line at  $y=0$ . This expansion towards the middle of the residual-time plot is more or less

symmetrical. However, this could indicate that some time-varying factors were excluded. As the units of analysis in this model are days, time-varying variables that change from day-to-day could confound the model, such as rainfall or program management.



**Figure 21: Residual V Time Plot for Daily Average Response Time Model**

To verify if a time-varying factor was excluded or not, a residual autocorrelation plot was created. If the model fits the time series data well, the residuals should mostly be white noise. The ACF can be seen in Figure 24 below. According to this figure, the model has captured the data well as there is no significant autocorrelation with the only significant spike occurring at a lag order of 5. While the model could be improved, it is unlikely to correct for this one outlier.



**Figure 22: Residual Autocorrelation**

### 7.1.1.3 Sensitivity Analysis

During the construction of the model, some observations were excluded. These included all data that occur before the peak response time on November 5<sup>th</sup>, 2012 as well as all observations equal to zero or below. The model constructed should be robust to the inclusion of this additional data. For the sake of this sensitivity analysis, only the additional dates were included to capture more data, as a negative response time and a response time of zero do not make intuitive sense.

A data table with the results from including all dates in the data can be seen in Appendix 12.1. The significance of the parameters does not change drastically when including all the dates when running the model. However, the coefficient values do change, with the coefficient for time and the first order lag decreasing and the coefficient for the constant increasing. This yields slightly different conclusions. In this case, daily average response time increased from 6.22 days to 9.37 days as opposed to the original conclusion of an increase from 6.05 days to 9.13 days. This is not a large increase in estimated time and residual analysis shows little residual variation with time and little to no residual autocorrelation. Diagrams for residual analysis can be seen in Appendix 12.2. These

residual analysis diagrams indicate that the models chosen, and conclusions drawn from the model, are relatively robust to including the previously excluded dates.

#### **7.1.1.4 Summary**

According to the average daily response time model, the average daily response time had a statistically significant relationship with time and has increased since the initiation of MCN. Starting from a value of 6.05 days, average daily response time has increased to 9.13 days. This increase does not occur between two time points with equivalent malaria transmission levels, as the analysis started from a low malaria transmission time point in October and ended in the middle of the peak malaria transmission season in June. However, the periodicity in the data should have been controlled for using the Fourier terms. While this increase in response time could be real, there are limitations in the data that reduce the validity of the results. First, the Fourier terms forced the model into a fixed sinusoidal pattern that is likely overestimating response time. Second, the data had numerous missing values and only consisted of two years of observations. Time series regression works best with complete data. Furthermore, as this analysis was focusing on long-term trends in response time, more years of data could make this time-series regression model the data better. Thus, while the model estimates that response time has increased, this should not be taken as an indicator that MCN is performing less effectively.

As this analysis could not control for the workload DMSOs face or the district where the cases were detected, this conclusion is a bird's eye view of how the surveillance system is working. A deeper analysis will be presented in the next section, which uses the case response time model in Equation 3.

## 7.1.2 Case Response Time Model

### 7.1.2.1 Model Construction

In constructing the Case Response Time Model, the same Fourier terms were used from the daily average response time model in addition to new variables of District, Reported Cases, and Household Size. The model used a GEE as data were likely correlated by DMSOs and a backwards stepwise estimation using LR tests was used to choose the best model. A table depicting each step of the backwards estimation method can be seen in Appendix 13. At the national level, the final model can be seen below in Equation 7.

#### Equation 7: Final Case Response Time Model

$$\text{Response time} = \beta_0 + \beta_1 t + \beta_2 \text{District} + \beta_3 \sin\left(\frac{2\pi t}{365}\right) + \beta_4 \cos\left(\frac{2\pi t}{365}\right) + \beta_5 \sin\left(\frac{4\pi t}{365}\right)$$

### 7.1.2.2 Case Level Response Time Model Estimates

When running the GEE, an exchangeable correlation structure was used as was a negative binomial family to specify the distribution of the individual case response times. As a general estimating equation uses robust standard errors to account for clustering, no additional specification for doing so was necessary. Just as in the daily average response model, the Fourier terms were nuisance variables and do not need to be interpreted directly. Table 9 below provides model estimates for the trend of **response time per case** and the coefficient, standard errors, and p-values for each variable are listed.

**Table 9: Final Model Estimates for Case Level Response Time**

Variable	Estimate (IRR)	Standard Error	p-value
<b>Time (Days)</b>	0.9998046	0.0001305	0.134
<b>District</b>			
<u>Urban</u>	1.000000	----	----
<u>West</u>	1.164853	0.1657158	0.283
<u>South</u>	1.182498	0.1665715	0.234
<u>North A</u>	0.4408682	0.0691817	0.000
<u>North B</u>	1.073299	0.1631935	0.642
<u>Central</u>	0.8801491	0.1169009	0.336
<u>Wete</u>	0.1823631	0.03454	0.000
<u>Mkoani</u>	0.4701114	0.1899357	0.000
<u>Micheweni</u>	1.095079	0.1712646	0.561
<u>ChakeChake</u>	0.3860666	0.0725682	0.000
<b>Fundamental Harmonic</b>			
<u>Sine</u>	0.8933621	0.0281659	0.000
<u>Cosine</u>	1.493078	0.0583797	0.000
<b>Second Harmonic</b>			
<u>Sine</u>	0.9209475	0.03034276	0.013
<b>Constant</b>	10.699921	1.261829	0.000

The most important finding is that at the case level, there is no significant association with response time and time, even after accounting for periodicity and the district of the cases. Furthermore, since no significant association was found between response time and workload (number of reported cases and household size), they were excluded from the model. There does appear to be significant differences in response time for districts, however. Using the district “Urban” as the referent group, the following districts had a statistically significant difference in response time: North A, Wete, Mkoani, and ChakeChake. Average response time in North A is 44% of the response time in Urban; In Wete it is 18.24% of that in Urban; In Mkoani it is 47% of that in Urban; and in ChakeChake it is 38.31% of that in Urban. Table 10 on the next page provides a summary of mean response times for all districts. Those districts in which a statistically significant difference in response time was found have been highlighted.

**Table 10: Average Response Time per District**

<b>District</b>	<b>Response Time (Days)</b>
<u>Urban</u>	8.72
<u>West</u>	11.58
<u>South</u>	11.4
<u>North A</u>	4.07
<u>North B</u>	10.34
<u>Central</u>	8.03
<u>Wete</u>	1.36
<u>Mkoani</u>	4.01
<u>Micheweni</u>	11.99
<u>ChakeChake</u>	3.28

### **7.1.2.3 District Level Analysis**

As significant differences were found in certain districts, additional models were run for each district. As mentioned in the previous chapter, a negative binomial regression was used to model response time in each district and a backwards stepwise method was used to select the best model. These models can be Appendix 14-1. Not all models had statistically significant coefficient estimates for the three main variables of interest: time, number of reported cases, and number of household members. Appendix 14-2 summarizes the information from all 10 district level models.

The district level analysis indicates inconsistent association of response time with time and work load. While response time has decreased in the South, North A, North B, and Micheweni district over time it has increased in the Urban, West, and Central district. On the other hand, response time increases as the number of reported cases increases in the Urban, South, Wete, and ChakeChake district but seems to decrease in North A and Mkoani district. Lastly, response time increases as the number of household members in the index case's household increases in the West, North B, Wete, and ChakeChake district but decreases in the Urban and North A district. This information can be seen in Table 11 below.

**Table 11: District Level Response Time Model Coefficient Associations**

Response Time	Time	Reported Cases	Household Size
<u>Increases</u>	<ul style="list-style-type: none"> <li>• Urban</li> <li>• West</li> <li>• Central</li> </ul>	<ul style="list-style-type: none"> <li>• Urban</li> <li>• South</li> <li>• Wete</li> <li>• ChakeChake</li> </ul>	<ul style="list-style-type: none"> <li>• West</li> <li>• North B</li> <li>• Wete</li> <li>• ChakeChake</li> </ul>
<u>Decreases</u>	<ul style="list-style-type: none"> <li>• South</li> <li>• North A</li> <li>• North B</li> <li>• Micheweni</li> </ul>	<ul style="list-style-type: none"> <li>• North A</li> <li>• Mkoani</li> </ul>	<ul style="list-style-type: none"> <li>• Urban</li> <li>• North A</li> </ul>

Most of the district level models displayed heteroscedasticity in their residuals, with the same downward trend seen in the daily average response time model. A spot check of residuals for these models indicated that overestimation was not associated with a time period. As a result, the overestimation of the model is likely again the result of the use of Fourier terms, which tend to force fixed sinusoidal patterns into the estimates. While heteroscedasticity does not invalidate the findings, it does slightly weaken them. Despite these limitations, the results do present crucial findings on the surveillance systems. This inconsistent relationship of explanatory factors with response time indicates how dependent response time is on the district and behavior of DMSOs. For example, while response time increases as reported cases increase in the Urban district, the opposite happens in North A. Much more interesting is how differently response time is associated with work load across the districts. As a result, investigating how DMSOs interact with MCN is crucial to place these findings in their context, findings which will be presented in the next section.

### 7.1.3 Summary

The models used in the analysis above yield different findings. The daily average model indicates that as a whole response time has increased over time in Zanzibar at a rate of 0.068% per day. However, the case level model for the entirety of Zanzibar yields inconclusive results, with time and response time having a statistically insignificant relationship. However, when the case level data

are stratified by district different results were found. While response time has increased in the Urban, West, and Central districts it has decreased in the South, North A, North B, and Micheweni districts. Furthermore, response-time's relationship with the number of reported case and the size of the index case's household also varies. While these disparate results could be a product of random variation, it could also indicate that the follow-up process is conducted differently in each district. However these findings should be drawn upon carefully due to limitations of the data and model.

The data have large gaps in the time-series due largely to no cases having been reported, a loss to follow-up, or clerical errors in data storage. Furthermore, the time series data start at a time of the year when malaria transmission and response time are low and ends at a time of the year when malaria transmission and response time are high. Lastly, only 2 years of response time data were available. For time series analysis to be conducted well, more years of data are usually needed. As a result, this time series data are complex to model. While Fourier terms were deemed the best method to use to control for the periodicity in the data, they placed a limit on the model by forcing a fixed sinusoidal pattern. Additional flexibility could have prevented the over-estimation that occurred, and additional data could help model the temporal process better.

Regardless, the daily average and district level models highlight how response time in MCN has changed. The district level models are in particular important as they illustrate that response time varies widely in Zanzibar. As DMSOs are at the heart of the follow-up process, these findings make their interaction with MCN critical. The next section will provide findings from both a survey and focus groups with all DMSOs in Zanzibar, highlighting their interaction with the surveillance system and difficulties they face.

## ***7.2 Stakeholder Analysis***

This section will present the findings on DMSOs' interaction with MCN, centered on 5 global themes: transportation, completeness and accuracy of recorded data at health facilities, the

follow-up process and household member testing, DMSO proactive-ness & resilience, and technical problems. First, findings from surveys will be presented. Afterwards, the emergent themes will be presented. This section will then present findings from the focus groups conducted with DMSOs and will conclude with a short discussion combining findings from the surveys and focus groups.

## **7.2.1 Survey Results**

A survey was sent to all DMSOs working on Zanzibar. Out of the 12 DMSOs on the island of Unguja, only 10 provided responses to survey. The district excluded from analysis was North B. All DMSOs from Pemba responded to the surveys.

### **7.2.1.1 Transportation Availability**

The first theme investigated was transportation. Engaging this topic was essential, as DMSOs had to rely heavily on transportation to follow-up up at the health facility level and household level. When asked if they had adequate transportation to reach either the health facility or index case's household, the DMSOs responded mostly in affirmation. While 9 out of the 10 respondents in Unguja reported they had adequate transportation to reach health facilities, only 3 of the 8 DMSOs in Pemba reported the same. On the other hand, 8 out of 10 respondents in Unguja reported having adequate transportation to reach patient's homes, while 4 out of 8 DMSOs in Pemba reported the same. These results clearly indicate that transportation access is a more pertinent issue for DMSOs in Pemba.

### **7.2.1.2 Health Facility Follow-Up**

#### Incomplete Records

The next theme examined was the completeness and accuracy of recorded data at health facilities. DMSOs were first asked if they frequently encountered incomplete malaria case records in the malaria case register (MCR) at health facilities. They were additionally asked what categories of

data they noticed was missing most often. In response to the first question, 8 DMSOs of the 10 respondents in Unguja responded that they did encounter incomplete records. In Pemba, 7 DMSOs of the 8 DMSOs on the island responded they encountered incomplete records.

In addition to incomplete records being found, DMSOs additionally reported that categories crucial to the patient follow-up process were missing. The most frequently reported, more than 50% of the time, missing categories of data amongst the two islands were: reference number in the outpatient directory; household card ID number (a form of address); and contact cell number. The responses to categories of data missing can be seen in Table 12 below.

**Table 12: Categories of Data in Malaria Case Registers Reported Missing by DMSOs**

Categories Missing	Island	
	Unguja (n=10)	Pemba (n=8)
Data of Positive Results	0	0
Reference # in OPD	6	7
Name	1	0
Age	0	0
Sex	0	0
Shehia (sub-district)	0	0
Village	3	2
Mjumbe/Sehemu (Shehia leader)	4	0
Household Card ID#	6	4
Head of Household Name	3	1
Contact Cell Number	8	6
Treatment Given	2	0
Overnight Travel	1	2
Places Travel	1	0

Missing data at the health facility is a problem not only for the follow-up process but also for the entire surveillance system. As a result, it was important to know why such data were not collected. Though not a perfect measure, DMSOs were asked to provide their thoughts on why such

data were not collected by the health facilities. Their responses could be divided into two categories: (1) patient inability or unwillingness to provide information and (2) high health facility traffic and facility personnel miscommunication and reliance on DMSOs. A description of DMSO responses can be seen below.

1. Patient inability or unwillingness to provide information: Both DMSOs in Unguja and Pemba noticed that patients often did not have the ability to provide the necessary information and came to the health facility unprepared to provide the information. This was most pronounced, as the table above indicates, with patient cell phone numbers. DMSOs theorized that patients either did not have a phone number to provide or could not remember their number. This could also explain why information on Shehia leader and household card number was often missing. However, a portion of this missing information could be attributed, according to DMSOs, to patients being foreigners or new-comers to their village. Apart from inability to provide information, one DMSO from Unguja offered that a reason for missing data was that patients were unwilling to provide information.
2. High health facility traffic and facility personnel miscommunication and reliance on DMSOs: When following-up on cases at health facilities, DMSOs noted that high patient volume at facilities can explain why complete information is not filled in the MCR. They believe that this results in health facility personnel filling out the MCR by memory. Furthermore, DMSOs reported that miscommunication existed between personnel who made diagnosis and those who recorded the cases. This was attributed, according to DMSOs, to lack of training or lack of motivation on the part of health facility personnel. These reasons, in addition to reliance on DMSOs to collect full information, explained why facilities did not collect full information
- 3.

### Incorrect Records

In addition to finding incomplete records, DMSOs also reported finding incorrectly filled out MCRs. In Unguja, 8 of the 10 respondents reported to find incorrect answers in MCRs whereas in Pemba, only 1 of the 8 DMSOs reported to find incorrect answers. DMSOs reported they were able to verify diagnostic information in the MCR by cross checking data in the laboratory (diagnostic) records book and other registers found in the health facility. However, verifying information on the patient, such as age, address, shehia (sub-district), and village names, relied more on the follow-up process..

### **7.2.1.3 Household Follow-Up**

Though DMSOs were able to correct some information at the health facility, many still reported difficulty in locating the household. In Unguja, all 10 respondents reported difficulties; while in Pemba 6 of the 8 DMSOs reported difficulty. When asked what caused problems, the majority of DMSOs reported that missing or incorrect information in MCRs were the primary reasons. Full and correct records, they maintained, would be enough to find the households. However, some DMSOs stated that additional information could be useful, such as names of neighbors.

Difficulties in the follow-up process were not unique to finding the household but were also encountered when DMSOs tested household members for malaria. In Unguja, 9 of the 10 respondents reported finding difficulties in testing household members. In Pemba, 3 of the 8 DMSOs reported finding difficulties in testing household members.

### Testing Household Members

Testing household members for malaria is critical for finding additional cases in a hot spot. As such, it was important to understand what contributed to difficulties. DMSOs elaborated on

various reasons, and their responses can be broken down into two categories: (1) lack of consent and (2) lack of awareness. A description of DMSO responses can be seen below.

1. Lack of consent: Often times, DMSOs encountered resistance by household members to be tested for malaria. Most of the time, this was due to a fear of being pricked for the RDT test. Other times, household members did not feel sick and did not see the need to get tested.
2. Lack of awareness: DMSOs noted that individuals in the household did not know the follow-up would occur. In addition to a lack of awareness, DMSOs noted that there was often confusion as to why a follow-up was conducted to the household. While some members simply were not aware of the importance of malaria testing, others thought that HIV being tested instead.

#### 7.2.1.4 Follow-Up Delay

In addition to discovering the obstacles encountered through the follow-up process it was important to assess DMSOs perception of how long it took them to follow-up on cases. As mentioned in chapter 4, ZAMEP has a goal of 48 hours within which cases must be followed-up to the household.. While not a perfect measure, self-reported time taken to follow up will be important to understand how well DMSOs perceive they are doing their jobs. Table 13 below depicts DMSOs' assessment of their own follow-up time.

**Table 13: DMSO Self-Assessment of Follow-Up Time**

Follow-up Time	Island	
	Unguja (n=10)	Pemba (n=8)
Less than 1 day	1	1
1-2 days	6	2
2 days	1	0
2-3 days	1	3
3 days or more	1	2

While DMSOs report to follow-up on cases in less than 48 hours, this does not necessarily mean that they do. A cause for concern is the fact that some DMSOs did report it took them longer than the 48-hour time-frame to follow-up. As such, discovering the source of follow-up delay is crucial. DMSOs reported various reasons that a delay could occur, and they fall into 4 broad categories: (1) Health facility division of labor miscommunication, (2) Case Load and Location & Patient Contact and Compliance, (3) Transportation and, (4) Network Connectivity Issues

1. Health Facility division of labor miscommunication: DMSOs reported they notice a misconception of roles amongst facility personnel and between themselves and facility personnel. In relation to the former, DMSOs stated that personnel often saw case recording and reporting as the sole responsibility of those who received the training. In relation to the latter, DMSOs reported that facility staff often requested them to partake in tasks at the facility that resided outside their responsibilities. This especially made it more time intensive to verify information in MCRs. An additional contributing factor to delays DMSOs reported was difficulty in finding the required facility personnel during working hours at facilities.
2. Case Load and Location & Patient information, contact, and compliance: DMSOs cited a major reason for delays to be high caseload or cases being spread out. However, when cases were few in number and close together DMSOs reported that incomplete information recorded at the health facility contributed to delays. When information was not missing, contacting the patient was the largest source of delay, as patients could be out of reach when called. Furthermore, capturing all household members contributed to delays, as it required revisits for those who were out of the house during the initial follow-up.
3. Transportation: DMSOs noted they experienced problems in access to transportation. Even when access was possible, they cited fuel shortages at stations to contribute to delays in addition to untimely reimbursement for fuel. As cases could be far apart from each other, or

require frequent re-visiting to capture the full household, the latter issue made timely follow-up problematic.

4. Network Issues: Network coverage was reported to extremely poor at times. Though this did not delay the actual collection of information, it did delay the sending of information to ZAMEP. Often times, DMSOs had to travel out of their way to receive a signal strong enough to send data.

### 7.2.1.5 Technical Issues

DMSOs use Coconut Surveillance through tablets and can therefore encounter technical problems that are relevant for MCN. All DMSOs were first asked the frequency of problems encountered and then the sources of technical problems. As seen in Table 14 below, the frequency of problems range from less than 4 times a year to more than once a month, with no clear trend. However, the sources of problems encounter are heavily focused on network coverage. As the above section on follow-up delay notes, network coverage problems contribute to the delay of sending case and household information.

**Table 14: Technical Issues Faced by DMSOs**

	Island	
	Unguja (n=10)	Pemba (n=8)
<b>Frequency of Problems</b>		
Less than 4 times a year	2	1
4 times a year or more	3	0
Once a month	1	2
More than once a month	4	3
<b>Sources of Technical Problems</b>		
Tablet broken	0	1
SIM card failure	1	0
Battery Issues	1	0
Network Coverage	10	8

### 7.2.1.6 Peak Season

The peak season in Zanzibar can be a problematic time for DMSOs to follow-up on cases within 48 hours. As such, DMSOs were asked what issues contributed most to difficulty in following-up on time. High caseload and spread out cases were emphasized heavily in DMSO responses; however they were more problematic for DMSOs in Unguja. For example, while 7 out of 10 respondents in Unguja reported that high case load contributed to difficulties in following up during the peak season, only 4 out of 8 DMSOs in Pemaba reported the same. Furthermore, 8 out of 10 respondents in Unguja reported that highly spaced out cases created problems for following up on time during the peak season, while only 5 out of 8 DMSOs in Pemba reported the same.

### 7.2.2 Emergent Themes

The analysis of survey responses gave way to the following themes:

- Efficiency of MCN: This is an underlying and fundamental theme of the survey results, and is presented in transportation issues and case investigation issues, etc. This theme was probed further in the focus groups to gain additional details on roadblocks not discussed in survey responses.
- Transportation: Though DMSOs initially reported that transportation was available to reach both the health facility and household, they later reported that transportation issues could cause delays in response time. As a result, it was important to understand what issues they faced and when.
- Errors and inconsistencies in MCRs: DMSOs almost unanimously reported that inconsistencies and errors existed in the MCR. However, they did not specify what kinds of errors or inconsistencies they found. This information would be important to improve case recording at health facilities and streamline response to detected cases.

- Prioritization of Cases: DMSOs in Unguja and Pemba noted that delays often occurred when case load was high and if cases were spread far apart. Determining the prioritization of cases is integral to interpreting overall response time of MCN
- Patient unwillingness to provide information and distrust of the follow-up: This was another commonly cited issue that cannot be ignored. Understanding what was at the heart of resistance and distrust would strengthen MCN.
- Peak Season: The peak season of MCN is a time when MCN is most tested. DMSOs stressed that high caseload and distance between cases can contribute to slower response time during the peak season. This theme was investigated further to understand what other roadblocks were specific to the peak season or more pronounced during the peak season.
- Network Issues when sending case and household information: This was the last major issue the DMSOs cited they faced when following-up on cases. As MCN receives all its information from USSD notifications and data sent via tablets, understanding how DMSOs worked around this problem was crucial.

These themes formed the backbone of the inquiry within focus group and questions and probes were derived from them. The section below presents findings from the focus groups.

### **7.2.3 Focus Group Results**

Though not all DMSOs responded to the initial surveys, all DMSOs attended the focus groups scheduled (12 in Unguja and 8 in Pemba). Both focus groups were conducted for just over an hour. The findings will be presented in order of themes discussed above.

#### Efficiency of MCN

The information garnered during focus groups was more or less the same as those found in the survey responses, with DMSOs placing stress on incorrect errors found in record books and

difficulty testing household members. However, additional details were gained regarding the ability to respond to newcomers to Zanzibar, and people being known by nicknames in their communities.

DMSOs stressed that people who had moved to Zanzibar (or a new district) often could not provide the information necessary for follow up, and as a result those cases could not be traced. Additionally, other DMSOs noted that oftentimes patients provided their full names at health facilities but were known by a nickname in their community. This also complicated the follow-up process.

#### Transportation:

DMSOs reiterated fuel reimbursement and shortages at stations to be a major issue in reaching health facilities and households. When this happened, public transportation was used. Both issues are problematic as contact tracing to the household was rife with obstacles that necessitated rescheduling and repeat visits. If patients were not home, for example, DMSOs revisited the household to attempt to collect full household information.

#### Errors & inconsistent information in MCRs

During their follow-up at health facilities, DMSOs noted that positivity of cases was recorded in the outpatient directory very consistently. However, actual information on the patient, especially household numbers (address) and phone numbers were not consistently filled out. While shehia and sheha information could be inaccurate or missing, the DMSOs noted that this was not often problematic as they are familiar with the community.

A source of error DMSOs noted here were health facilities failing to report cases. At times, DMSOs noticed cases in the MCR were not reported. When this occurred, DMSOs reported they requested health facilities to send cases via USSD notifications and then added case information into coconut surveillance.

### Prioritization of cases

DMSOs varied how they prioritized cases. Most DMSOs prioritized follow-ups on the order case notifications were received. Others prioritized them by the most recent case notifications received. Still other DMSOs prioritized them by distance. While some started with those in proximity, out of an obligation to help those closer to them, other DMSOs prioritized cases farther away from them. Lastly, some DMSOs prioritized by patient characteristics, with the heaviest consideration being children and pregnant women.

### Patient unwillingness to provide information & distrust of the follow up process

DMSOs believe that patients' unwillingness to provide information at the facility stems from a desire to not reveal their identity or a misunderstanding that a follow-up is needed at the household. This was confirmed by other DMSOs stating that often patients and family members were surprised to see them at the household. DMSOs echoed findings from the surveys that household members often refused to be tested for malaria due to a fear of needles and a misconception that HIV was being tested. However, it was also noted that permission to be tested often became easier if one household member agreed to be tested.

### Peak Season:

DMSOs responses to questions under this theme reiterated details in survey responses. A high caseload and large distance between cases were the primary obstacles and problems with transportation exacerbated those obstacles. Others stated that during the rainy season, physically getting to cases was problematic. This was pronounced in focus group discussions in Pemba, where some facilities and households are on outer lying smaller islands. The roads to reach those smaller islands often became flooded during the rainy season.

### Network Issues when sending case and household information

DMSOs reiterated problems previously stated in the surveys, that they frequently had to travel to areas with good signal to send data. Distance traveled ranged from 8-20km (5-12 miles). While the distance necessary to travel could interrupt response time, most DMSOs stressed that data collection was still possible and that the only problem was data transmission.

### **7.2.4 Summary**

The main issues that were raised during the investigation of DMSOs interaction with MCN were transportation issues, namely fuel shortages resulting in reliance on public transportation; erroneous, inconsistent, and missing information in MCRs at health facilities; resulting difficulties locating index case households and resistance to testing due to community members misconstruing testing for HIV; repeat visits being required to capture complete information on the household and household members; and network coverage. Additionally, DMSOs stressed in both surveys and focus groups that the following issues were the largest contributors to delays in the follow-up process: transportation, household contact & household member compliance for testing, and network coverage.

The focus groups echoed most findings from the surveys. However, they did provide new information regarding index case contact, case prioritization, physical accessibility to the index case household, and network coverage. DMSOs raised new details regarding patient contact during the focus groups: that full names were often provided at health facilities while patients were known by a nickname in their community. This behavior created difficulties for DMSOs locating the index case household. In addition to this new finding, more information regarding case prioritization was garnered. DMSOs reported a variety of practices. While some stated they followed-up on cases in the order received, others followed up on the most recently reported cases. These temporal inconsistencies were not the only finding. DMSOs additionally reported disparate behavior in

following-up on cases based on distance. While some stated they followed-up on cases closer to them first, others stated they followed-up on cases farther away from them first. Another finding related to physical accessibility when following-up on cases. This was more pronounced during the rainy season and was a larger factor on Pemba. As there are many outlying islands by Pemba, accessing these cases during the rainy season when roads can be flooded is difficult. Lastly, new information was raised regarding network connectivity. DMSOs reported needing to travel up to 8-20 km (5-12 miles) to be at a location with enough signal strength to send cases through Coconut Surveillance.

## 8.0 Discussion

### 8.1 Summary and Integration of Findings

This study finds that while the average daily response time in MCN has increased by 0.068% **per day** between October 5<sup>th</sup>, 2012 and July 31<sup>st</sup>, 2014 there is no statistically significant change in response time **per case**. The results of the average daily response time model are limited by the fact that Fourier terms forced the model into a fixed sinusoidal pattern, that the data had missing values, and that the data only had 2 years of observations.

A district level analysis indicates that not only was the average response times **per case** different in each district but that its association with time also varied by district. For example, while response time has increased in the Urban, West, and Central districts, it has decreased in the South, North A, North B, and Michewni districts. In addition to a variation in the association of response time with time between districts, additional variation was found in the association of response time with workload between districts.

It is possible that the varied association between response time and time by district is a product of the levels of malaria transmission at the beginning of the time series and the end. Recall that the available data started in October, a month when transmission levels are low, and ended in July, a month that falls in the midst of the peak malaria transmission season. However, this periodicity should have been accounted for through the inclusion of Fourier terms in the model. It is also possible that variation in the association of response time with time by district is purely a result of random variation in the response time data.

However, it is also possible that the differences in variation of response time with time **per case** are not an artifact of the available data. Stakeholder surveys and focus groups indicated a wide variety of issues regarding transportation, locating index case households, and resistance by household members for malaria testing. DMSOs reported often having to resort to public

transportation to reach both the health facility and household. If public transportation availability and speed are different in each district, this could explain why response time varied by district.

Another issue that DMSOs reported they frequently encountered was incomplete and erroneously filled out malaria case registers at health facilities. As this information is essential for the follow-up process, incorrect and missing data could undoubtedly increase response time. It is possible that districts with better response time had health facilities that more often correctly recorded information in the malaria case registers. DMSOs additionally reported that reasons for missing or erroneous information could possibly result from patients distrusting health facilities, a theme that was also discovered when testing household members for malaria. It may be possible that patient's trust of health facilities also varies by the district.

This distrust of health facilities was also a theme found when DMSOs tested household members for malaria. Some DMSOs noted that household members refused to take an RDT test for malaria out of fear their blood would be used to test for HIV. While this could be just a distrust of the use of their blood, it could also stem from a fundamental distrust of health care workers. Resistance to testing likely increased response time, it was defined as the time-span between when a case was reported and the last household member was tested. As household members' fear of the RDT test was not an issue raised by all DMSOs, this could be an issue that varies by district.

A last issue, brought up in the focus groups, was how cases were prioritized. DMSOs provided a variety of answers ranging between prioritizing cases furthest from them versus those closer to them to prioritizing cases reported most recently versus in the order they were received. This is a wide variety of prioritization methods used by DMSOs and could be a contributor to the variation of response times by district.

In addition to the distrust of testing, DMSOs reported that index case patients and household members were often surprised to see them conduct a household follow-up. This indicated

either that proper messaging was not conducted at the health facility or that community members were on the whole unaware of this process. This lack of messaging could also vary by district and explain the variation in response times by district.

Findings from DMSO surveys and focus groups did not garner information on why response time per case association with workload differed by district. However, this variation is likely a function of DMSO motivation.

## ***8.2 Limitations of the Study***

While this study does provide actionable results for ZAMEP, it does have some limitations. The major limitations for the timelines analysis was the fixed sinusoidal pattern that Fourier terms forced the model into, the short time frame of the data, and the presence of missing values. The first limitation, the fixed sinusoidal pattern that Fourier terms created, limit the flexibility of the model. Using sine and cosine terms forces the model to predict a wave form with crests and troughs to have the same height throughout the time series. The data are likely more complex than this and a model with more flexibility could have fit the data better.

The second limitation in the timeliness analysis is the short time frame of the data. While two years of daily case reporting data did provide a large sample size, capturing periodic trends over just two years is difficult. Additional years of data could have made modeling long-term trends in response time easier and the results more reliable.

The third limitation is the presence of missing values. Frequently, there were missing values in the response time data. Here missing means that on certain days, no malaria case data are available. It is unknown whether this is a result of no cases being diagnosed to report on those days, or if health facilities failed to report positive cases on those days. Regardless of the reason, these missing values limit the modeling of a time series analysis. This is more of a problem for the daily average

response time model, as it relied on the use of lag-terms to account for autocorrelation. However, these missing values could still limit the modeling of the case response time models.

The limitation of the stakeholder analysis is the lack of transcription of focus groups. While notes were taken and analyzed, a transcript of the focus group discussion could have enabled a more robust qualitative analysis.

### **8.3 Recommendations**

Despite these limitations, the findings of the study provide actionable results. Using both the timeliness analysis and stakeholder analysis, the following recommendations are proposed.

1. Cross-train Health Facility Employees: DMSOs have reported that record management at health facilities is inconsistent. As poor record management has been reported to cause delays in the follow-up, this inconsistency should be resolved. The difference in record keeping quality, however, can be leveraged. ZAMEP usually provides training directly to health facilities. The inconsistency in record keeping indicates that this form of training delivery has not resonated with health facility personnel. Thus, rather than ZAMEP providing training directly to health facilities, the facilities themselves should cross-train each other, with ZAMEP acting as a supervisory role. If facilities with strong record keeping and management, as identified by DMSOs, deliver the training, their recommendations may be more accepted.
2. Issue a communication strategy to Health Facilities to stress their role in MCN: While training for health facilities will be important for record keeping, messaging should be conducted to emphasize facilities' role in the MCN system. This training should address improving communication of the follow-up process to patients. Health facilities should inform positively diagnosed patients that a DMSO will be visiting them. An additional approach to improving this communication could be to request a potential date/time for

follow-up. This would allow DMSOs to schedule their follow-ups in a more efficient manner.

3. Zero reporting: Within MCN, there were days when no cases were reported to ZAMEP. It is unknown if this is a result of cases not being diagnosed on those days or a result of diagnosed cases not being reported. Thus, MCN should be adapted to allow for zero reporting, a form of case reporting where health facilities report all cases detected even if zero cases were detected (WHO 1999) . While MEEDS already allows this reporting in its weekly aggregate, any errors in recording cases in the MCN process will propagate into MEEDS. Not only can zero-reporting strengthen MCN in tracking cases, it can help monitor reporting activity, reduce missing data, and identify locations with poor reporting.
4. Establish Standard Operating Procedures for the Follow-Up Process in Coconut Surveillance: An observation made when conducting DMSO focus groups was that DMSOs followed-up on cases in a variety of ways. This inconsistency in follow-up practices can distort the response time to cases in MCN. Standardized operating procedures should be put in place to reflect when and where malaria cases are reported. These can be implemented into Coconut Surveillance. Specifically, Coconut Surveillance should be modified to limit follow-up to the order in which case notifications were received. While allowing DMSOs flexibility in responding to cases is important as they themselves know the workload burden, the current flexibility does not allow for ZAMEP to accurately monitor the follow-up process. In addition to limiting the flexibility of the follow-up process, Coconut Surveillance should incorporate the scheduling system mentioned recommendation 2.
5. Engage community on malaria and low-transmission and MCN: DMSOs reported that household members often did not know about the follow-up process nor did not feel they needed to be tested for malaria. These obstacles contributed to delays in following-up,

according to DMSOs. As a result, information campaigns and/or sensitization efforts should be implemented. These should include information on the role of the DMSOs and the purpose of the follow-up. The information campaigns should also stress that despite the low-transmission levels of malaria, people are still at risk, with emphasis placed on asymptomatic malaria. By making communities aware of the follow-up and the risk of malaria, the information campaigns may make household members more willing to be tested when DMSOs visit for case follow-up.

6. Update Data Infrastructure: The current structure of data collected in MCN is highly valuable and contributes significantly to the assessment of incidence and interventions. However, a problem arises from the way data have been recorded. As mentioned in the methods section, data were cleaned for extraneous characters and standardization of data formats. For the purpose of future research on timeliness, the data formatting for time-stamps should be universalized in MCN. However, data cleaning events should not overwrite existing time-stamps, but should be a separate variable in the system.

## **8.4 Future Research Directions**

In addition to the recommendations made above, more research on challenges inherent during the follow-up process should to be conducted to provide a clear evidence base on which to make changes to MCN. Two critical future directions of research include community member perception of health facilities and health care workers and community member knowledge on MCN and the follow-up process. Findings from such research studies could provide actionable results that ZAMEP can implement to improve MCN. For example, discovering which factors are causing distrust of health facilities can underscore why misconceptions exist, allowing better targeting of interventions. Furthermore, discovering what knowledge community members have of MCN and the

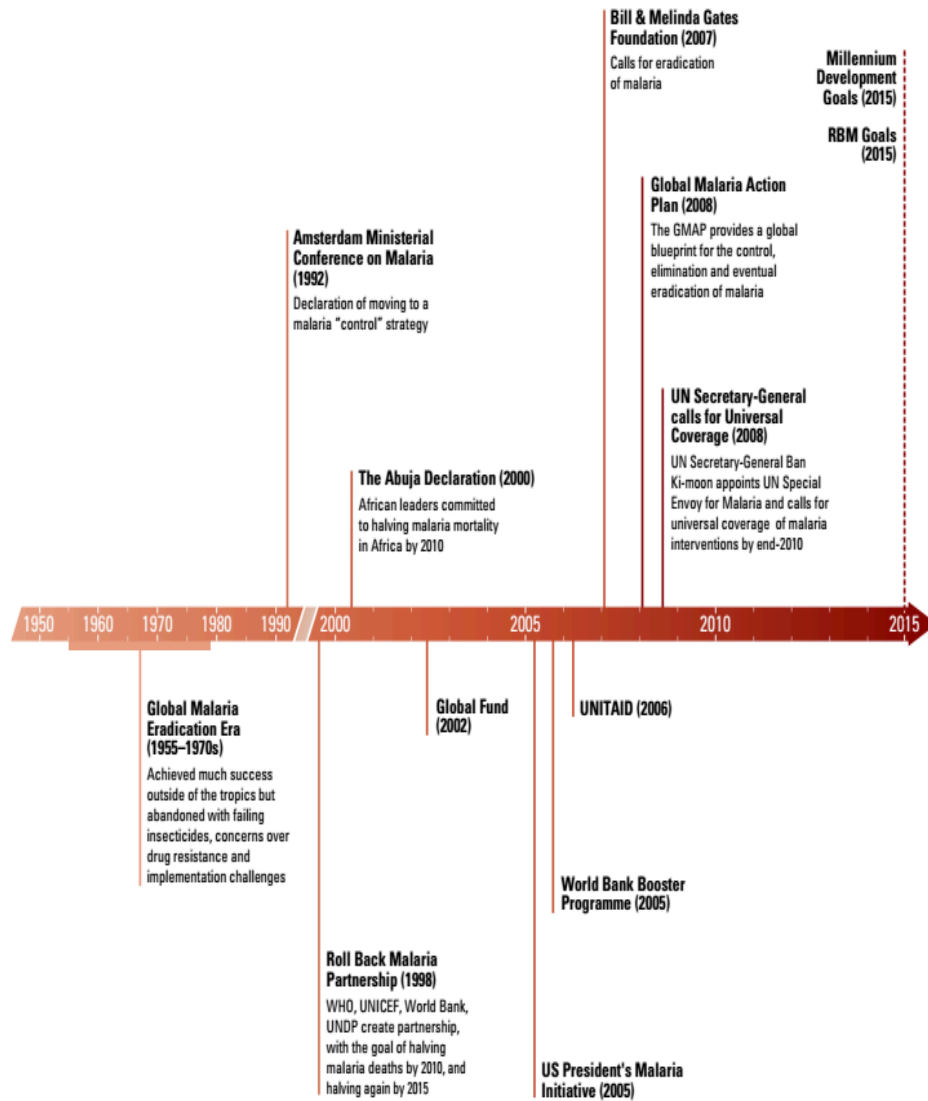
follow-up process can inform not only communication strategies but also the best information source.

## **8.5 Conclusion**

Average daily response time in Zanzibar's Malaria Case Notification surveillance system seems to have increased gradually from October 2012 to July 2014. However, response time to each case varies across Zanzibar, with improvements over time in some districts but not in others. While this finding may be an artifact of the available data, it may also be due to the different obstacles that DMSOs encountered, which includes transportation and misconceptions about and lack of awareness of the follow-up process. To improve MCN and achieve a more uniform operation ZAMEP should implement the operational recommendations listed above. Furthermore, the research recommendations on community member perceptions of health facilities and health workers and community member knowledge on MCN can inform the operational recommendations. Together, the information garnered from the research and operational recommendations can allow ZAMEP to strengthen MCN and bolster efforts to eliminate malaria in Zanzibar.

# Appendices

## Appendix 1: Timeline of Global Malaria Control Efforts



Source: (RBM 2011a)

## Appendix 2: MEEDS USSD Data Transmission Screenshots



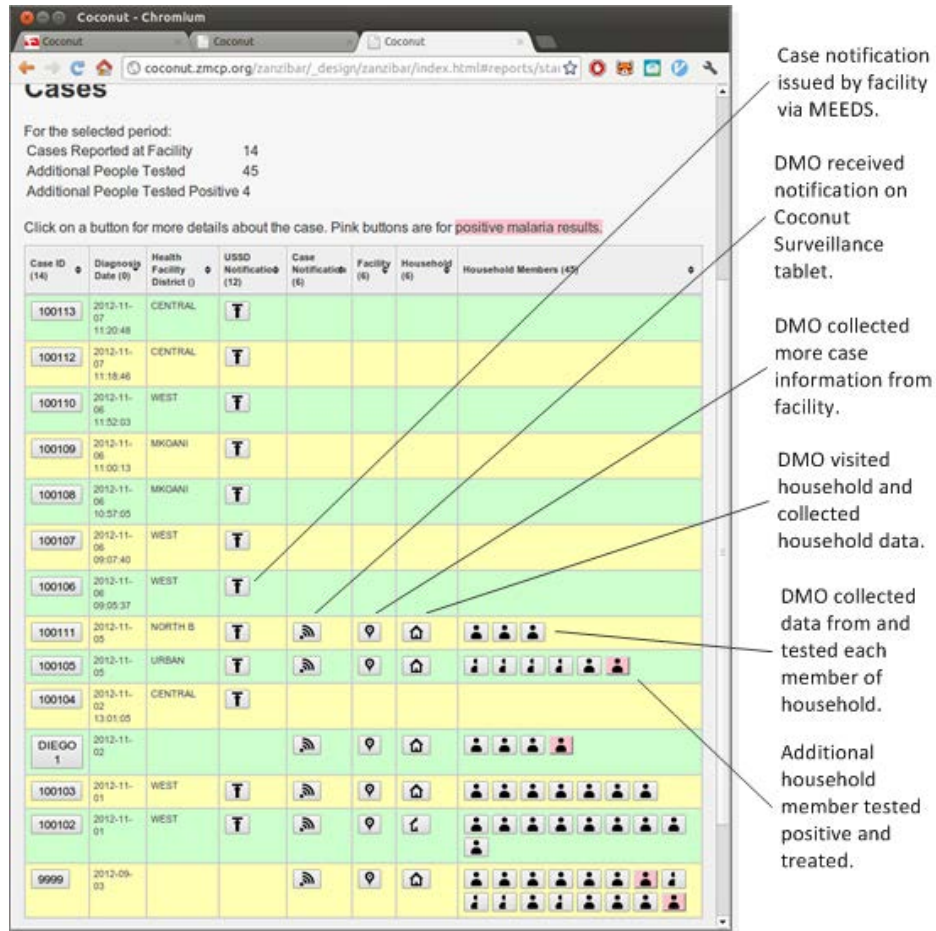
Source: (RTI 2013a)

## Appendix 3: Coconut Surveillance Screenshots

### Appendix 3.1 Coconut Surveillance Guided Protocol

Case Notification	Facility	Household	Household Members
Facility Name			
<input type="text" value="1"/>			
Malaria Case ID			
<input type="text"/>			
Shehia			
<input type="text"/>			
Name			
<input type="text"/>			
<input type="button" value="complete"/>			
Case Notification	Facility	Household	Household Members

## Appendix 3.2 Online Monitoring of Case Data Flow



Source: (RTI 2013c)

This diagram depicts how ZAMEP can track the flow of a case through MCN. If icons are present in the columns, it indicates that the step has been completed.

### **Appendix 4: Data Collected by Coconut Surveillance**

<u>Data Flow Step</u>	<u>Data Collected</u>
Case Notification	<ul style="list-style-type: none"> <li>• Case ID</li> <li>• Date of Creation and Final Edit</li> <li>• Facility Name</li> <li>• Patient Name</li> <li>• Shehia Name</li> </ul>
Health Facility	<ul style="list-style-type: none"> <li>• Date of Creation and Final Edit</li> <li>• Age</li> <li>• Contact Number</li> <li>• Patient Name</li> <li>• Head of Household Name</li> <li>• Travel History</li> <li>• Gender</li> <li>• Shehia Name</li> <li>• Village Name</li> <li>• Village Leader Name</li> </ul>
Household	<ul style="list-style-type: none"> <li>• Date of Creation and Final Edit</li> <li>• Household Geolocation</li> <li>• Last Date of IRS</li> <li>• Number of LLINs</li> <li>• Number of Sleeping spaces</li> <li>• Number of People in Household</li> <li>• Number of Household Members with fever</li> <li>• Number of Household Members with Malaria</li> </ul>
Household Family Members	<ul style="list-style-type: none"> <li>• Date of Creation and Final Edit</li> <li>• Patient Name</li> <li>• Age</li> <li>• Gender</li> <li>• Body Temperature</li> <li>• History of Fever</li> <li>• Travel History</li> <li>• Test Result</li> <li>• Sleep Under a Bednet</li> </ul>

**Appendix 5: PHSSR Research Agenda Domains & Thematic Sub-Areas**

<u>PHSSR Domain</u>	<u>Thematic Sub-Area</u>
<u>Public Health Workforce</u>	Enumeration
	Demand, Supply, and Shortages
	Diversity and Disparities
	Recruitment and Retention
	Workforce Competencies
	Educational Methods/Curricula
<u>Public Health System Structure and Performance</u>	System Boundaries/Size
	Public Health Agency Organization/Governance
	Inter-organizational Relationships/Partnership
	Performance Measurement/Quality Improvement/Accreditation
	Social Determinants of Health and Health Disparities
<u>Public Health Financing</u>	Fiscal Analysis
	Financing Mechanisms
	Costs/Performance/Outcomes
<u>Public Health Information &amp; Technology</u>	Capabilities to Assess and Monitor Health Outcomes
	Translation and Dissemination of Research Tested Public Health Strategies
	Information and Communication Technologies

Source: (Brownson, Fielding et al. 2013)

## **Appendix 6: CDC Updated Guidelines for Evaluating Public Health Surveillance Systems Checklist**

### **Checklist for Evaluating Public Health Surveillance Systems**

<b>Tasks for evaluating a surveillance system*</b>	<b>Page(s) in this report</b>
<input type="checkbox"/> Task A. Engage the stakeholders in the evaluation	4
<input type="checkbox"/> Task B. Describe the surveillance system to be evaluated	4–11
<input type="checkbox"/> 1. Describe the public health importance of the health-related event under surveillance	4– 5
<input type="checkbox"/> a. Indices of frequency	
<input type="checkbox"/> b. Indices of severity	
<input type="checkbox"/> c. Disparities or inequities associated with the health-related event	
<input type="checkbox"/> d. Costs associated with the health-related event	
<input type="checkbox"/> e. Preventability	
<input type="checkbox"/> f. Potential future clinical course in the absence of an intervention	
<input type="checkbox"/> g. Public interest	
<input type="checkbox"/> 2. Describe the purpose and operation of the surveillance system	5–10
<input type="checkbox"/> a. Purpose and objectives of the system	
<input type="checkbox"/> b. Planned uses of the data from the system	
<input type="checkbox"/> c. Health-related event under surveillance, including case definition	
<input type="checkbox"/> d. Legal authority for data collection	
<input type="checkbox"/> e. The system resides where in organization(s)	
<input type="checkbox"/> f. Level of integration with other systems, if appropriate	
<input type="checkbox"/> g. Flow chart of system	
<input type="checkbox"/> h. Components of system	
<input type="checkbox"/> 1) Population under surveillance	
<input type="checkbox"/> 2) Period of time of data collection	
<input type="checkbox"/> 3) Data collection	
<input type="checkbox"/> 4) Reporting sources of data	
<input type="checkbox"/> 5) Data management	
<input type="checkbox"/> 6) Data analysis and dissemination	
<input type="checkbox"/> 7) Patient privacy, data confidentiality, and system security	
<input type="checkbox"/> 8) Records management program	
<input type="checkbox"/> 3. Describe the resources used to operate the surveillance system	10–11
<input type="checkbox"/> a. Funding source(s)	
<input type="checkbox"/> b. Personnel requirements	
<input type="checkbox"/> c. Other resources	
<input type="checkbox"/> Task C. Focus the evaluation design	11–12
<input type="checkbox"/> 1. Determine the specific purpose of the evaluation	
<input type="checkbox"/> 2. Identify stakeholders who will receive the findings and recommendations of the evaluation	
<input type="checkbox"/> 3. Consider what will be done with the information generated from the evaluation	
<input type="checkbox"/> 4. Specify the questions that will be answered by the evaluation	
<input type="checkbox"/> 5. Determine standards for assessing the performance of the system	
<input type="checkbox"/> Task D. Gather credible evidence regarding the performance of the surveillance system	13–24
<input type="checkbox"/> 1. Indicate the level of usefulness	13–14
<input type="checkbox"/> 2. Describe each system attribute	14–24
<input type="checkbox"/> a. Simplicity	
<input type="checkbox"/> b. Flexibility	
<input type="checkbox"/> c. Data quality	
<input type="checkbox"/> d. Acceptability	
<input type="checkbox"/> e. Sensitivity	
<input type="checkbox"/> f. Predictive value positive	
<input type="checkbox"/> g. Representativeness	
<input type="checkbox"/> h. Timeliness	
<input type="checkbox"/> i. Stability	
<input type="checkbox"/> Task E. Justify and state conclusions, and make recommendations	24
<input type="checkbox"/> Task F. Ensure use of evaluation findings and share lessons learned	25

\* Adapted from *Framework for Program Evaluation in Public Health* [CDC. Framework for program evaluation in public health. MMWR 1999;48(RR-11)] and the original guidelines [CDC. Guidelines for evaluating surveillance systems. MMWR 1988;37(No. S-5)].

Source: (CDC 2001)

## Appendix 7: DMSO Survey

### DMSO Questionnaire

ZAMEP and RTI are conducting an evaluation of the MCN surveillance system. Information regarding how malaria cases are follow-up and technical problems you face is essential for the evaluation to be complete. Please complete this questionnaire as detailed as possible. If you wish to provide more details than space allows, please send additional comments to: [eeshan.khandekar.mcevaluation@gmail.com](mailto:eeshan.khandekar.mcevaluation@gmail.com) and include what district you work in to allow continuity of information.

Q 1: What District do you work in?

Q 2: Do you have adequate transportation to visit the following? (Tick all the apply)

- Health Facilities
- Patients Home's

Q 3: If did not check any of the options in the above question, please state problems that you encounter. (Tick all that apply)

- Do not have transportation means
- Transportation does not have enough fuel
- Transportation does not work for another reason
- Problems with roads
- Other, please describe \_\_\_\_\_

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Q 4: When you visit health facilities, are all the required fields in the MCN register filled out?

- Yes
- No

Q 5: If you answered no, please state what information is missing usually (Tick all that apply)

- |  |   |
|--|---|
| <input type="checkbox"/> Date of positive results        | <input type="checkbox"/> Mjumbe/Sehemu          |
| <input type="checkbox"/> Reference # in the OPD register | <input type="checkbox"/> Household card ID#     |
| <input type="checkbox"/> Name                            | <input type="checkbox"/> Head of Household name |
| <input type="checkbox"/> Age                             | <input type="checkbox"/> Contact mobile number  |
| <input type="checkbox"/> Sex                             | <input type="checkbox"/> Treatment given        |
| <input type="checkbox"/> Shehia                          | <input type="checkbox"/> Overnight travel       |
| <input type="checkbox"/> Village                         | <input type="checkbox"/> Places traveled -      |

*Q 6: If you see incomplete fields, do you know why health facilities have not filled these out? If so, please provide a brief explanation. (Only answer if you answered no to question 4).*

Answer:

*Q 7: Do you often find invalid answers in data fields for the MCN register?*

- Yes
- No

*Q 8: How do you determine the accuracy of the data in MCN registers?*

Answer:

*Q 9: Do you have difficulty following finding households to follow up on cases?*

- Yes
- No

*Q 10: If you answered yes to the above, please state why. If more information needs to be provided, also state what you need.*

Answer:

*Q 11: Do you have difficulty in testing household members?*

- Yes
- No

*Q 12: If you answered yes to the above, please state why.*

Answer:

*Q 13: On average how long does it take to follow-up on cases?*

- 1 day or less*
- 1- 2 days*
- 2 days*
- 2-3 days*
- 3 days or more*

*Q 14: If it takes longer than the recommended 48 hours to follow up, can you please explain challenges you face?*

Answer:

*Q 15: What do you believe can be done to overcome these challenges?*

Answer:

*Q 16: If you notice a significant number of cases (more than 5 cases in a week) when following up, do you notify the ZAMEP office?*

- Yes
- No

*Q 17: If private health facilities were added to the MCN surveillance system, would you still be able to follow-up on time?*

- Yes
- No

*Q 18: If the required time-frame to follow-up decreased, could you accommodate this?*

- Yes
- No

*Q 19: Is your tablet currently working?*

- Yes
- No

*Q 20: How often do you have technical problems with your tablet?*

- Less than 4 times a year
- 4 times a year or more
- Once a month
- More than once a month

*Q 21: In general, if you have problems with your tablet, what are they? (Tick all that apply)*

- Tablet broken
- SIM broken
- Battery issues
- Tablet lost or stolen
- Network Coverage

*Q 22: If problems relating to entering data into tablet related to network coverage, can you provide information on where this issue occurred?*

Answer:

*Q 23: During the peak season, do you have the following difficulties that can prevent case follow-up? (Tick all that apply)*

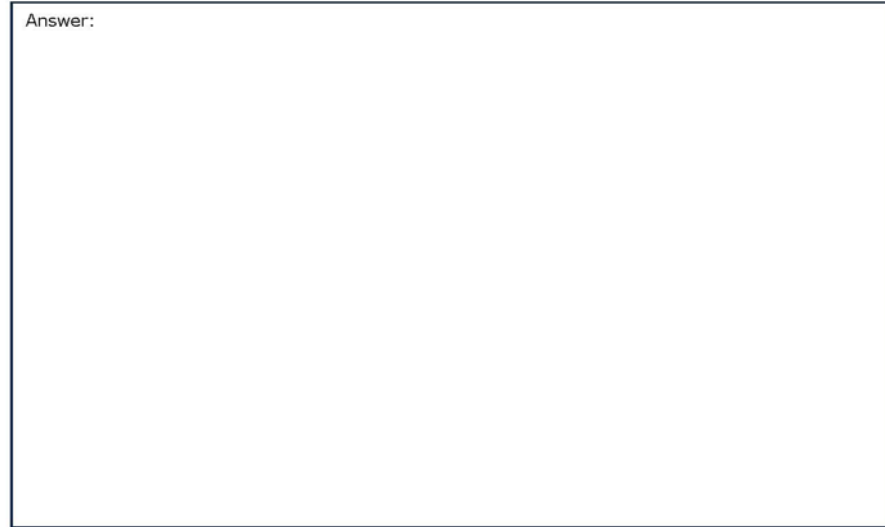
- Too many cases
- Cases are too far apart
- Other, please specify \_\_\_\_\_  
\_\_\_\_\_

*Q 24: If you have additional comments relating to the question above, please state them here.*

Answer:

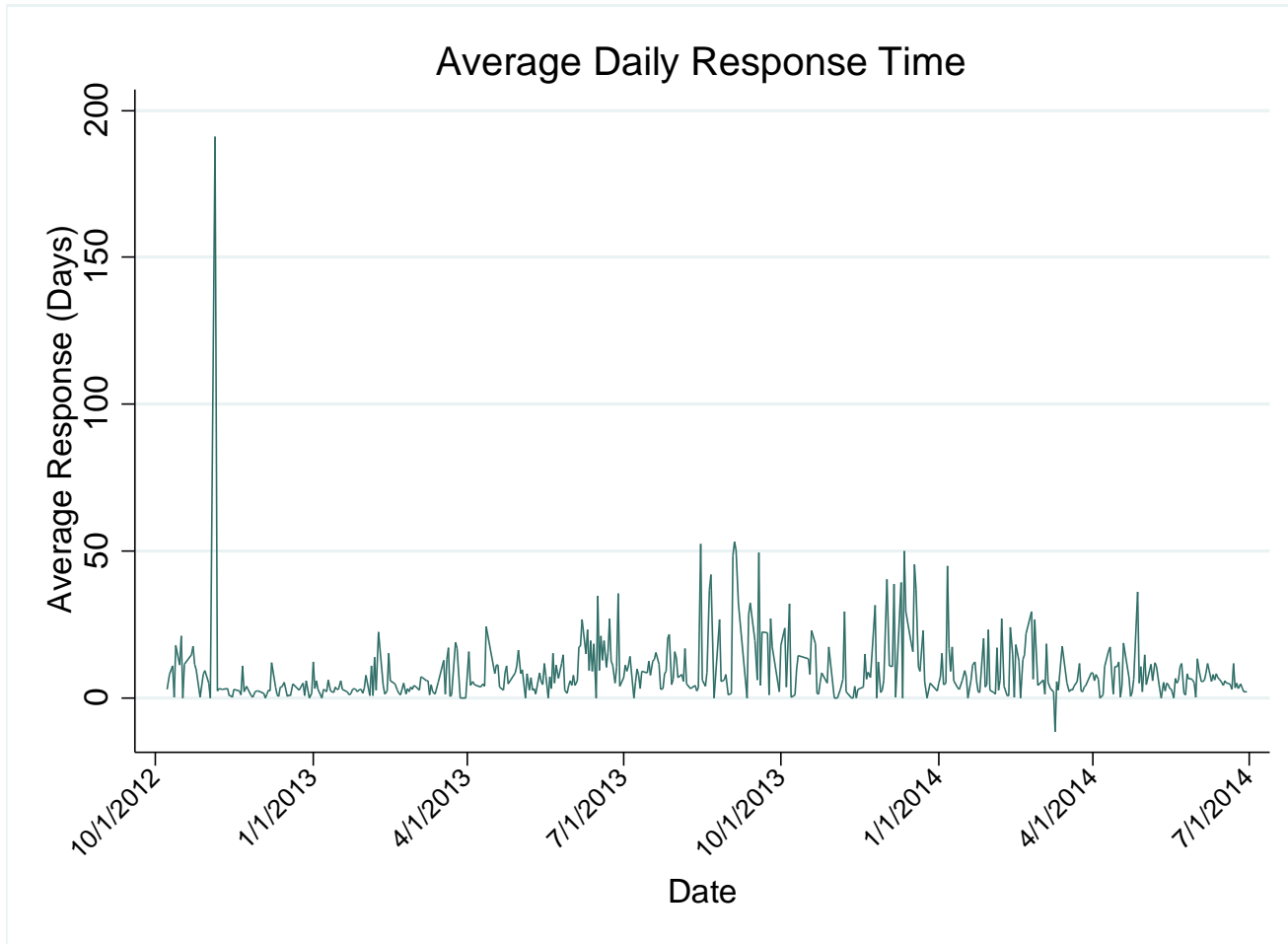
Q 25: Do you have any other comments or thoughts regarding MCN or your role?

Answer:



End of questionnaire  
THANK YOU FOR YOUR TIME AND INPUT!

**Appendix 8: Raw Complete Daily Average Response Time Data**



### **Appendix 9: Likelihood Ratio Tests Results**

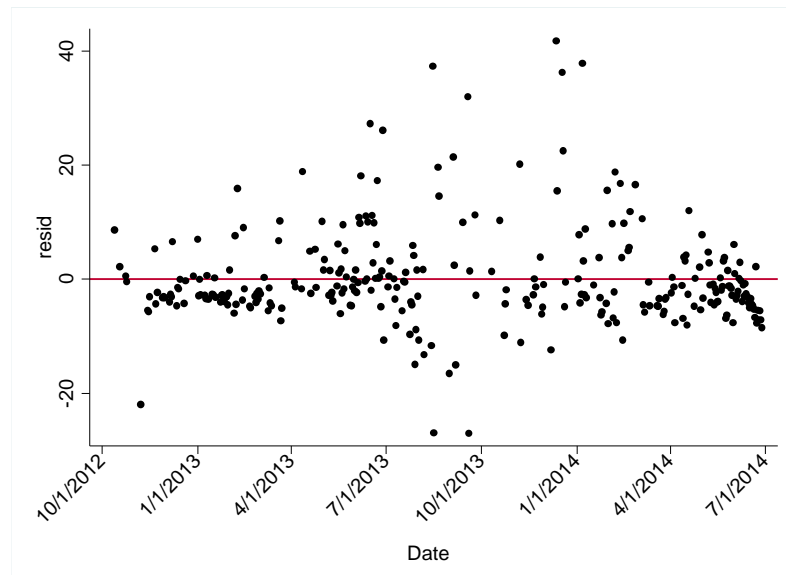
	<b>Likelihood Ratio Results</b>	
<b>Terms Added</b>	<u>Test Statistic</u>	<u>p-value</u>
<b>Adding Individually to Baseline</b>		
Case Count	0.56	0.4546
Response Time Lag 1	645.36	0.0000
Response Time Lag 2	774.21	0.0000
<b>Iterative Addition (New Baseline with Lag 1 term)</b>		
Response Time Lag 2	515.18	0.0000

## Appendix 10: Sensitivity Analysis for Daily Average Response Time Model (Model Check & Residual Check)

### Appendix 10.1: Model Estimates for Model with all Dates in Time Series

Daily Response Model with normal standard errors								
	Time (Days)	Response Lag 1	Response Lag 2	Sin (DayRank)	Cos (DayRank)	Sin (DayRank) 2nd Harmonic	Cos (DayRank) 2nd Harmonic	Constant
<b>Estimate</b>	1.000646	1.015705	1.007075	0.8177447	1.435058	0.7847742	1.062651	6.223354
<b>Standard Error</b>	0.000292	0.0056481	0.0050227	0.0574072	0.1286207	0.0583424	0.0785015	0.774437
<b>p-value</b>	0.027**	0.005**	0.157	0.004***	0.00***	0.001***	0.411	0.000***
* = significant at 0.1 level ** = significant at 0.05 level *** = significant at 0.01 level								
Daily Response Model with robust standard errors								
	Time (Days)	Response Lag 1	Response Lag 2	Sin (DayRank)	Cos (DayRank)	Sin (DayRank) 2nd Harmonic	Cos (DayRank) 2nd Harmonic	Constant
<b>Estimate</b>	1.000646	1.015705	1.007075	0.8177447	1.435058	0.7847742	1.062651	6.223354
<b>Standard Error</b>	0.000609	0.0062255	0.0079779	0.0712641	0.1404018	0.0661802	0.08555	0.803113
<b>p-value</b>	0.036**	0.011**	0.373	0.021**	0.00**	0.004***	0.450	0.000***
* = significant at 0.1 level ** = significant at 0.05 level *** = significant at 0.01 level								

## Appendix 10.2: Residual Analysis for Model with all Dates in Time Series



**Appendix 11: Forward Stepwise Model Estimation for the Case Response Time Data**

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	Full Model	Stepwise Models		
		Step1 Model	Step 2 Model	Final Model
<b>Day Rank</b>	0.9998012 (0.128)	0.9998014 (0.128)	0.9998039 (0.134)	0.9998043 (0.134)
<b>District</b>				
West	1.138923 (0.361)	1.139107 (0.360)	1.15128 (0.325)	1.164853 (0.283)
South	1.16843 (0.269)	1.168003 (0.270)	1.191082 (0.217)	1.182498 (0.234)
North A	0.4469972 (0.000)	0.4465613 (0.000)	0.4441829 (0.000)	0.4408682 (0.000)
North B	1.077484 (0.623)	1.076911 (0.625)	1.08257 (0.604)	1.073299 (0.642)
Central	0.8714267 (0.302)	0.8710002 (0.3000)	0.8823368 (0.349)	0.8801491 (0.336)
Wete	0.1838926 (0.000)	0.1839156 (0.000)	0.1836153 (0.000)	0.1823631 (0.000)
Mkoani	0.4805075 (0.000)	0.480437 (0.000)	0.4757307 (0.000)	0.4701114 (0.000)
Micheweni	1.104533 (0.523)	1.104183 (0.525)	1.100384 (0.543)	1.095079 (0.561)
ChakeChake	0.3937791 (0.000)	0.3939508 (0.000)	0.3884883 (0.000)	0.3860666 (0.000)
<b>Fundamental Harmonic</b>				
Sin	0.8979599 (0.001)	0.8981929 (0.001)	0.8891216 (0.000)	0.8933621 (0.000)
Cosine	1.533426 (0.000)	1.532925 (0.000)	1.525874 (0.000)	1.493078 (0.000)
<b>Second Harmonic</b>				
Sin	0.9244104 (0.019)	0.9246405 (0.019)	0.9249908 (0.018)	0.9209475 (0.013)
Cosine	1.059723 (0.086)	1.059483 (0.086)	1.050174 (0.136)	
<b>Work Load</b>				
Reported Cases	1.005134 (0.331)	1.005119 (0.332)		
Household Size	1.000575 (0.933)			
Constant	10.68354 (0.000)	10.71337 (0.000)	10.84498 (0.000)	10.69921 (0.000)

## Appendix 12: District Level Models & Estimations

### Appendix 12.1: District Models

District	Model
Urban	$Response\ Time = \beta_0 + \beta_1 t + \beta_2 \sin\left(\frac{2\pi t}{365}\right) + \beta_3 \cos\left(\frac{2\pi t}{365}\right) + \beta_4 Reported\ Cases + \beta_5 Household\ Size$
West	$Response\ Time = \beta_0 + \beta_1 t + \beta_2 \sin\left(\frac{2\pi t}{365}\right) + \beta_3 \cos\left(\frac{2\pi t}{365}\right) + \beta_4 \sin\left(\frac{4\pi t}{365}\right) + \beta_4 \cos\left(\frac{4\pi t}{365}\right) + \beta_6 Household\ Size$
South	$Response\ Time = \beta_0 + \beta_1 t + \beta_3 \sin\left(\frac{4\pi t}{365}\right) + \beta_3 Reported\ Cases$
North A	$Response\ Time = \beta_0 + \beta_1 t + \beta_2 \sin\left(\frac{2\pi t}{365}\right) + \beta_3 \cos\left(\frac{4\pi t}{365}\right) + \beta_4 Reported\ Cases + \beta_5 Household\ Size$
North B	$Response\ Time = \beta_0 + \beta_1 t + \beta_2 \sin\left(\frac{2\pi t}{365}\right) + \beta_3 \cos\left(\frac{4\pi t}{365}\right) + \beta_4 Household\ Size$
Central	$Response\ Time = \beta_0 + \beta_1 t + \beta_2 \sin\left(\frac{2\pi t}{365}\right) + \beta_3 \cos\left(\frac{4\pi t}{365}\right)$
Wete	$Response\ Tme = \beta_0 + \beta_1 t + \beta_2 \cos\left(\frac{2\pi t}{365}\right) + \beta_3 Reported\ Cases + \beta_3 Household\ Size$
Mkoani	$Response\ Time = \beta_0 + \beta_1 t + \beta_2 \cos\left(\frac{2\pi t}{365}\right) + \beta_3 \cos\left(\frac{4\pi t}{365}\right) + \beta_4 Reported\ Cases$
Micheweni	$Response\ Time = \beta_0 + \beta_1 t + \beta_2 \cos\left(\frac{2\pi t}{365}\right) + \beta_3 \sin\left(\frac{4\pi t}{365}\right) + \beta_4 \cos\left(\frac{4\pi t}{365}\right)$
ChakeChake	$Response\ Time = \beta_0 + \beta_1 t + \beta_2 Reported\ Cases + \beta_3 Household\ Size$

## Appendix 12.2: District Model Estimates

District	Key Explanatory Variables Estimates (IRR)			
	Time	Reported Cases	Number of Household Members	Constant
<u>Urban</u>	1.000615 (0.072)*	1.079307 (0.003)***	0.9529969 (0.002)***	6.855611 (0.000)***
<u>West</u>	1.000627 (0.018)*		1.027268 (0.000)***	1065825 (0.048)*
<u>South</u>	0.9951484 (0.000)***	1.038488 (0.000)***		15.13284 (0.000)***
<u>North A</u>	0.9991577 (0.022)**	0.9166837 (0.001)***	0.9383604 (0.013)***	9.383604 (0.013)***
<u>North B</u>	0.9984006 (0.000)***		1.05271 (0.012)**	12.34443 (0.000)***
<u>Central</u>	1.002186 (0.000)***			3.436854 (0.000)
<u>Wete</u>	0.9990405 (0.138)	1.217991 (0.001)***	1.102567 (0.014)***	0.54981 (0.11)
<u>Mkoani</u>	1.001189 (0.151)	0.7041668 (0.001)***		3.949984 (0.001)***
<u>Micheweni</u>	0.9979103 (0.000)***			18.68936 (0.000)***
<u>ChakeChake</u>	1.00071 (0.288)	0.7239058 (0.041)**	0.8595194 (0.000)***	11.3134 (0.000)
*** significant at 0.01 ** significant at 0.05 * significant at 0.1				

## References

- Abdulla, S., P. Alonso, F. Binka, P. Graves, B. Greenwood, R. Leke, E. Malik, K. Marsh, S. Meek, K. Mendis, A. Schapira, L. Slutsker, M. Tanner, N. Valecha, N. White, A. Bosman, R. Cibulskis, V. D'Acremont, B. D'Souza, M. Lynch, A. Mnzava, V. Moorthy, R. Newman, P. Olumese, A. Rietveld, P. Ringwald and W. H. O. M. P. Advisory (2013). "Malaria Policy Advisory Committee to the WHO: Conclusions and Recommendations of March 2013 Meeting." Malaria Journal **12**: 213.
- AFM (2008). Keeping Malaria out of Zanzibar. Washington, D.C., Africa Fighting Malaria.
- Akbari, H., R. Majdzadeh, A. R. Foroushani and A. Raeisi (2013). "Timeliness of Malaria Surveillance System in Iran." Iranian Journal of Public Health **42**: 39-47.
- Alonso, P. L., H. Y. Atta, C. Drakeley, T. Eisele, S. I. Hay, M. H. Rodriguez Lupez, S. Meek, R. Steketee, L. Slutsker and E. R. A. C. G. M. mal (2011). "A Research Agenda for Malaria Eradication: Monitoring, Evaluation, and Surveillance." Plos Medicine **8**(1): e1000400.
- Alonso, P. L., G. Brown, M. Arevalo-Herrera, F. Binka, C. Chitnis, F. Collins, O. K. Doumbo, B. Greenwood, B. F. Hall, M. M. Levine, K. Mendis, R. D. Newman, C. V. Plowe, M. Henry Rodriguez, R. Sinden, L. Slutsker and M. Tanner (2011). "A Research Agenda to Underpin Malaria Eradication." Plos Medicine **8**(1): e1000406.
- Altarum Institute, CDC, Robert Wood Johnson Foundation and National Coordinating Center for Public Health Services and Systems Research (2012). "A National Research Agenda for Public Health Services and Systems." American Journal of Preventative Medicine **42**(5 Suppl 1): S72-78.
- Bejon, P., T. N. Williams, A. Liljander, A. M. Noor, J. Wambua, E. Ogada, A. Olotu, F. H. A. Osier, S. I. Hay, A. Farnert and K. Marsh (2010). "Stable and Unstable Malaria Hotspots in Longitudinal Cohort Studies in Kenya." Plos Medicine **7**(7): e1000304.
- Bettcher, D. W., S. Sapirie and E. H. T. Goon (1998). "Essential Public Health Functions: Results of the International Delphi Study." World Health Statistics Quarterly **51**(1): 44-54.

- Bhaskaran, K., A. Gasparrini, S. Hajat, L. Smeeth and B. Armstrong (2013). "Time Series Regression Studies in Environmental Epidemiology." International Journal of Epidemiology **42**(4): 1187-1195.
- Bhattarai, A., A. S. Ali, S. P. Kachur, A. Martensson, A. K. Abbas, R. Khatib, A.-w. Al-Mafazy, M. Ramsan, G. Rotllant, J. F. Gerstenmaier, F. Molteni, S. Abdulla, S. M. Montgomery, A. Kaneko and A. Bjorkman (2007). "Impact of Artemisinin-Based Combination Therapy and Insecticide-Treated Nets on Malaria Burden in Zanzibar." Plos Medicine **4**(11): 1784-1790.
- Bousema, T., C. Drakeley, S. Gesase, R. Hashim, S. Magesa, F. Mosha, S. Otieno, I. Carneiro, J. Cox, E. Msuya, I. Kleinschmidt, C. Maxwell, B. Greenwood, E. Riley, R. Sauerwein, D. Chandramohan and R. Gosling (2010). "Identification of Hot Spots of Malaria Transmission for Targeted Malaria Control." Journal of Infectious Diseases **201**(11): 1764-1774.
- Bousema, T., J. T. Griffin, R. W. Sauerwein, D. L. Smith, T. S. Churcher, W. Takken, A. Ghani, C. Drakeley and R. Gosling (2012). "Hitting Hotspots: Spatial Targeting of Malaria for Control and Elimination." Plos Medicine **9**(1): e1001165.
- Bousema, T., R. M. Youssef, J. Cook, J. Cox, V. A. Alegana, J. Amran, A. M. Noor, R. W. Snow and C. Drakeley (2010). "Serologic Markers for Detecting Malaria in Areas of Low Endemicity, Somalia, 2008." Emerging Infectious Diseases **16**(3): 392-399.
- Brownson, R. C., E. A. Baker, T. L. Leet, K. N. Gillespie and W. R. True (2011a). Evaluating the Program or Policy. Evidence-Based Public Health. R. C. Brownson, E. A. Baker, T. L. Leet, K. N. Gillespie and W. R. True. New York, New York, Oxford University Press.
- Brownson, R. C., E. A. Baker, T. L. Leet, K. N. Gillespie and W. R. True (2011b). The Need for Evidence Based Public Health. Evidence-Based Public Health. R. C. Brownson, E. A. Baker, T. L. Leet, K. N. Gillespie and W. R. True. New York, New York, Oxford University Press.
- Brownson, R. C., J. E. Fielding and C. M. Maylah (2013). "Evidence-Based Decision Making to Improve Public Health Practice." Frontiers in Public Health Services and Systems Research **2**(2): 2.
- Brownson, R. C., J. E. Fielding and C. A. Maylahn (2009). Evidence-Based Public Health: A Fundamental Concept for Public Health Practice. Annual Review of Public Health. **30**: 175-201.

- Brownson, R. C., J. G. Gurney and G. H. Land (1999). "Evidence-Based Decision Making in Public Health." Journal of public health management and practice : JPHMP 5(5): 86-97.
- Cargo, M. and S. L. Mercer (2008). The Value and Challenges of Participatory Research: Strengthening its Practice. Annual Review of Public Health. 29: 325-350.
- CDC (1999). "Framework for Program Evaluation in Public Health." MMWR 48(RR-11).
- CDC (2001). "Updated Guidelines for Evaluating Public Health Surveillance Systems: Recommendations From the Guidelines Working Group." MMWR 50(RR-13).
- CDC (2004). "Framework for Evaluating Public Health Surveillance Systems for Early Detection of Outbreaks." MMWR 53(RR-05).
- CDC (2006). Lesson Five: Public Health Surveillance. Principles of Epidemiology in Public Health Practice: An Introduction to Applied Epidemiology in Public Health Practice. Atlanta, GA, Centers for Disease Control and Prevention.
- CDC (2011). Enhancing Surveillance Manual for the Surveillance of Vaccine-Preventable Diseases. Atlanta, GA, Centers for Disease Control and Prevention.
- Choi, B. C. K. (2012). "The Past, Present, and Future of Public Health Surveillance." Scientifica 2012: 875253-875253.
- Cohen, J. M., B. Moonen, R. W. Snow and D. L. Smith (2010). "How Absolute is Zero? An Evaluation of Historical and Current Definitions of Malaria Elimination." Malaria Journal 9: 213.
- Cohen, J. M., D. L. Smith, C. Cotter, A. Ward, G. Yamey, O. J. Sabot and B. Moonen (2012). "Malaria Resurgence: A Systematic Review and Assessment of its Causes." Malaria Journal 11: 122.
- Cressman, G. M., M. V. McKay, A. W. Al-Mafazy, M. M. Rasman, A. S. Ali, I. A. Garimo, H. Mkali and J. J. M. Ngondi (2014). Using Mobile Technology to Help Eliminate Malaria in Zanzibar, RTI International, ZAMEP.
- Dannenbergs, A. L., R. Bhatia, B. L. Cole, S. K. Heaton, J. D. Feldman and C. D. Rutt (2008). "Use of Health Impact Assessment in the US - 27 Case Studies, 1999-2007." American Journal of Preventive Medicine 34(3): 241-256.

- Declich, S. and A. O. Carter (1994). "Public-Health Surveillance: Historical Origins, Methods and Evaluation " Bulletin of the World Health Organization **72**(2): 285-304.
- Dyal, W. W. (1995). "Ten Organizational Practices of Public Health: A Historical Perspective." American Journal of Preventive Medicine **11**(6): 6-8.
- E2Pi (2011). Maintaining the Gains in Malaria Control: The Health and Economic Benefits of Sustaining Control Measures. Maintaining the Gains in Malaria Control. G. Yamey, UCSF Global Health Group.
- Ernst, K. C., S. O. Adoka, D. O. Kowuor, M. L. Wilson and C. C. John (2006). "Malaria Hotspot Areas in a Highland Kenya Site Are Consistent In Epidemic and Non-Epidemic Years and Are Associated with Ecological Factors." Malaria Journal **5**: 78.
- Evidence-Based Medicine Working Group (1992). "Evidence-Based Medicine. A New Approach to Teaching the Practice of Medicine." JAMA **268**(17): 2420-2425.
- Eylenbosh, W. J. and N. D. Noah (1988). Historical Aspects. Surveillance in Health and Disease. W. J. Eylenbosh and N. D. Noah. New York, Oxford University Press.
- Feachem, R. and O. Sabot (2008). "A New Global Malaria Eradication Strategy." Lancet **371**(9624): 1633-1635.
- Feachem, R. G. A. and MEG (2009). Shrinking the Malaria Map: A Guide on Malaria Elimination for Policy Makers, UCSF Global Health Group.
- Feachem, R. G. A., A. A. Phillips, J. Hwang, C. Cotter, B. Wielgosz, B. M. Greenwood, O. Sabot, M. Henry Rodriguez, R. R. Abeyasinghe, T. A. Ghebreyesus and R. W. Snow (2010). "Shrinking the Malaria Map: Progress and Prospects." The Lancet **376**(9752): 1566-1578.
- Fisman, D. N. (2007). Seasonality of Infectious Diseases. Annual Review of Public Health. **28**: 127-143.
- Foege, W. H., R. C. Hogan and L. H. Newton (1976). "Surveillance Projects for Selected Diseases." International Journal of Epidemiology **5**(1): 29-37.
- Foldy, S. L. (2004). "Linking Better Surveillance to Better Outcomes." MMWR **53** **Suppl**: 12-17.

- Ford, E. W., W. J. Duncan and P. M. Ginter (2003). "The Structure of State Health Agencies: a Strategic Analysis." Medical Care Research and Review **60**(1): 31-57.
- Forney, J. R., A. J. Magill, C. Wongsrichanalai, J. Sirichaisinthop, C. T. Bautista, D. G. Heppner, R. S. Miller, C. F. Ockenhouse, A. Gubanov, R. Shafer, C. C. DeWitt, H. A. Quino-Ascurra, K. E. Kester, K. C. Kain, D. S. Walsh, W. R. Ballou and R. A. Gasser (2001). "Malaria Rapid Diagnostic Devices: Performance Characteristics of the ParaSight F Device Determined in a Multisite Field Study." Journal of Clinical Microbiology **39**(8): 2884-2890.
- Freedman, D. A. (2006). "On the So-Called "Huber Sandwich Estimator" and "Robust Standard Errors"." American Statistician **60**(4): 299-302.
- Fullman, N., R. Burstein, S. S. Lim, C. Medlin and E. Gakidou (2013). "Nets, Spray or Both? The Effectiveness of Insecticide-Treated Nets and Indoor Residual Spraying in Reducing Malaria Morbidity and Child Mortality in Sub-Saharan Africa." Malaria Journal **12**: 62.
- Gething, P. W., A. P. Patil, D. L. Smith, C. A. Guerra, I. R. Elyazar, G. L. Johnston, A. J. Tatem and S. I. Hay (2011). "A New World Malaria Map: Plasmodium Falciparum Endemicity in 2010." Malaria Journal **10**: 378.
- Global Fund. (2006). "Implementation of a New Malaria Treatment Policy in Zanzibar." from <http://portfolio.theglobalfund.org/en/Grant/Index/ZAN-102-G01-M-00>.
- Global Fund. (2009). "Consolidation of Malaria Control Through the Use of Artemisinin-Based Combination Therapy and Insecticide Treated Nets.", from <http://portfolio.theglobalfund.org/en/Grant/Index/ZAN-404-G04-M>.
- Greenwood, B. M. (1989). "The Microepidemiology of Malaria and its Importance to Malaria Control." Transactions of the Royal Society of Tropical Medicine and Hygiene **83**(Suppl.): 25-29.
- Gueye, C. S., K. C. Sanders, G. N. L. Galappaththy, C. Rundi, T. Tobgay, S. Sovannaroth, Q. Gao, A. Surya, G. D. Thakur, M. Baquilod, W.-j. Lee, A. Bobogare, S. L. Deniyage, W. Satimai, G. Taleo, N. M. Hung, C. Cotter, M. S. Hsiang, L. S. Vestergaard and R. D. Gosling (2013). "Active Case Detection for Malaria Elimination: a Survey Among Asia Pacific Countries." Malaria Journal **12**: 358.
- Harris, J. K., K. E. Beatty, J. D. Lecy, J. M. Cyr and R. M. Shapiro, II (2011). "Mapping the Multidisciplinary Field of Public Health Services and Systems Research." American Journal of Preventive Medicine **41**(1): 105-111.

- Hsiang, M. S., J. Hwang, S. Kunene, C. Drakeley, D. Kandula, J. Novotny, J. Parizo, T. Jensen, M. Tong, J. Kemere, S. Dlamini, B. Moonen, E. Angov, S. Dutta, C. Ockenhouse, G. Dorsey and B. Greenhouse (2012). "Surveillance for Malaria Elimination in Swaziland: A National Cross-Sectional Study Using Pooled PCR and Serology." Plos One 7(1): e29550.
- IOM (1988). The Future of Public Health. Washington, D.C., National Academy Press.
- IOM (1997). Improving Health in the Community: A Role of Performance Monitoring. Washington, D.C., National Academy Press.
- Jajosky, R. A. and S. L. Groseclose (2004). "Evaluation of Reporting Timeliness of Public Health Surveillance Systems for Infectious Diseases." BMC Public Health 4(29).
- Jenicek, M. (1997). "Epidemiology, Evidenced-Based Medicine, and Evidence-Based Public Health." Journal of Epidemiology 7(4): 187-197.
- Jones, G., S. Le Hello, N. Jourdan-da Silva, V. Vaillant, H. de Valk, F. Weill and Y. Le Strat (2014). "The French Human Salmonella Surveillance System: Evaluation of Timeliness of Laboratory Reporting and Factors Associated with Delays, 2007 to 2011." Eurosurveillance 19(1): pii-20664.
- Kohatsu, N. D., J. G. Robinson and J. C. Torner (2004). "Evidence-Based Public Health: An Evolving Concept." American Journal of Preventive Medicine 27(5): 417-421.
- Langmuir, A. D. (1963). "Surveillance of Communicable Diseases of National Importance." New England Journal of Medicine 268(4): 182-192.
- Langmuir, A. D. (1976). "William Farr: Founder of Modern Concepts of Surveillance." International Journal of Epidemiology 5(1): 13-18.
- Le Menach, A., A. J. Tatem, J. M. Cohen, S. I. Hay, H. Randell, A. P. Patil and D. L. Smith (2011). "Travel Risk, Malaria Importation and Malaria Transmission in Zanzibar." Scientific Reports 1(93).
- Lenaway, D., P. Halverson, S. Sotnikov, H. Tilson, L. Corso and W. Millington (2006). "Public Health Systems Research: Setting a National Agenda." American Journal of Public Health 96(3): 410-413.
- Leowski, J. (1998). "Essential Public Health Functions--Their Place in the Health-For-All Policy for the 21st Century." World Health Statistics Quarterly 51(1): 55-55.

- Lin, W., S. Chen, N. Seguy, Z. Chen, K. Sabin, J. G. Calleja and M. Bulterys (2012). "Is the HIV Sentinel Surveillance System Adequate in China? Findings From an Evaluation of the National HIV Sentinel Surveillance System." Western Pacific Surveillance and Response Journal 3(4): 76-85.
- Macauley, C. (2005). "Aggressive Active Case Detection: A Malaria Control Strategy Based on the Brazilian Model." Social Science & Medicine 60(3): 563-573.
- MEG. (2013). "Regional Initiatives for Elimination." 2014, from <http://www.malariaeliminationgroup.org/resources/regional-and-cross-border-initiatives-elimination>.
- Miller, C. A., K. S. Moore, T. B. Richards and C. McKaig (1994). "A Screening Survey to Assess Local Public Health Performance." Public Health Reports 109(5): 659-664.
- Millward, L., M. Kelly and D. Nutbeam (2003). Public Health Intervention Research: The Evidence. London, Health Development Agency.
- MOHSW (2009). Zanzibar Comprehensive Multi-year Plan 2010-2014. The Revolutionary Government of Zanzibar, Ministry of Health and Social Work.
- MOHSW (2010). Assessment of the Availability of Health Services in Terms of Accessibility and Quality of Health Care. The Revolutionary Government of Zanzibar, Ministry of Health and Social Work.
- Moonen, B., J. M. Cohen, R. W. Snow, L. Slutsker, C. Drakeley, D. L. Smith, R. R. Abeyasinghe, M. Henry Rodriguez, R. Maharaj, M. Tanner and G. Targett (2010a). "Operational Strategies to Achieve and Maintain Malaria Elimination." Lancet 376(9752): 1592-1603.
- Moonen, B., J. M. Cohen, A. J. Tatem, J. Cohen, S. I. Hay, O. Sabot and D. L. Smith (2010b). "A Framework for Assessing the Feasibility of Malaria Elimination." Malaria Journal 9: 322.
- Moro, M. L. and A. McCormick (1988). Surveillance for Communicable Disease. Surveillance in Health and Disease. W. J. Eyles and N. D. Noah, Oxford University Press.
- Najera, J. A. (1989). "Malaria and the Work of WHO." Bulletin of the World Health Organization 67(3): 229-243.

- Najera, J. A. (2001). "Malaria Control: Achievements, Problems and Strategies." Parassitologia (Rome) **43**(1-2): 1-89.
- Najera, J. A., M. Gonzalez-Silva and P. L. Alonso (2011). "Some Lessons for the Future from the Global Malaria Eradication Programme (1955-1969)." Plos Medicine **8**(1): e1000412.
- Nicolay, N., P. Garvey, N. Delappe, M. Cormican and P. McKeown (2010). "Completeness and Timeliness of Salmonella Notifications in Ireland in 2008: A Cross Sectional Study." BMC Public Health **10**: 568.
- Nsubuga, P., M. E. White, S. B. Thacker, M. A. Anderson, S. B. Blount, C. V. Broome, T. M. Chiller, V. Espitia, R. Imtiaz, D. Sosin, D. F. Stroup, R. V. Tauxe, M. Vijayaraghavan and M. Trostle (2006). Public Health Surveillance: A Tool for Targeting and Monitoring Interventions. Disease Control Priorities in Developing Countries, 2nd Edition. D. T. Jamison, J. G. Breman, A. R. Measham et al.: 997-1015.
- Ohrt, C., K. Roberts, H. Sturrock, J. Wgbreit and R. Gosling (2014). Surveillance Systems to Facilitate Malaria Elimination Malaria Elimination Background Paper Series and Strategy Briefs, UCSF Global Health Group.
- Okell, L. C., A. C. Ghani, E. Lyons and C. J. Drakeley (2009). "Submicroscopic Infection in Plasmodium falciparum-Endemic Populations: A Systematic Review and Meta-Analysis." Journal of Infectious Diseases **200**(10): 1509-1517.
- PAHO (2008). The Essential Public Health Functions as a Strategy for Improving Health Systems Performance: Trends and Challenges Since the Public Health in the Americas Initiative, 2000-2007. Washington, D.C., Pan American Health Organization.
- PATH (2014). Zanzibar Trip Report. Project DIAMETER (Diagnostic for Malaria Elimination Towards Eradication). Seattle, Washington, PATH.
- Payne, D. (1988). "Use and Limitations of Light-Microscopy For Diagnosing Malaria at the Primary Health-Case Level." Bulletin of the World Health Organization **66**(5): 621-626.
- Phillips-Howard, P. A., B. L. Nahlen, M. S. Kolczak, A. W. Hightower, F. O. ter Kuile, J. A. Alaii, J. E. Gimnig, J. Arudo, J. M. Vulule, A. Odhacha, S. P. Kachur, E. Schoute, D. H. Rosen, J. D. Sexton, A. J. Oloo and W. A. Hawley (2003). "Efficacy of Permethrin-Treated Bed Nets in the Prevention of Mortality in Young

Children in an Area of High Perennial Malaria Transmission in Western Kenya." American Journal of Tropical Medicine and Hygiene **68**(4): 23-29.

PMI (2006). 2006 Tanzania Malaria Country Action Plan, U.S. Presidents Malaria Initiative.

PMI (2007). 2007 Tanzania Malaria Operational Plan, U.S. Presidents Malaria Initiative.

PMI (2015). 2015 Tanzania Malaria Operational Plan, U.S. Presidents Malaria Initiative.

Rachas, A., E. Nakoune, J. Bouscaillou, J. Paireau, B. Selekon, D. Senekian, A. Fontanet and M. Kazanji (2014). "Timeliness of Yellow Fever Surveillance, Central African Republic." Emerging Infectious Diseases **20**(6): 1004-1008.

RBM (2008). Global Malaria Action Plan. Geneva, Switzerland.

RBM (2011a). A Decade of Partnership and Results. Progress and Impact Series. Geneva, World Health Organization.

RBM (2011b). Eliminating Malaria: Learning from the Past, Looking Ahead. Progress and Impact Series, Roll Back Malaria Partnership.

Reijn, E., C. M. Swaan, M. E. E. Kretzschmar and J. E. van Steenberg (2011). "Analysis of Timeliness of Infectious Disease Reporting in the Netherlands." BMC Public Health **11**: 409.

Riera-Montes, M. and I. Velicko (2011). "The Chlamydia Surveillance System in Sweden Delivers Relevant and Accurate Data: Results from the System Evaluation, 1997-2008." Euro Surveill **16**(27).

Romaguera, R., R. R. German, and D. N. Klaucke (2000). Evaluating Public Health Surveillance Principles and Practices of Public Health Surveillance. S. M. a. C. Teutsch, R. E. . New York, New York, Oxford University Press: 176-193.

RTI. (2009). "A Model for Fighting Malaria in Mainland Tanzania and Zanzibar ", from [http://www.rti.org/brochures/tanzania\\_zanzibar\\_malaria.pdf](http://www.rti.org/brochures/tanzania_zanzibar_malaria.pdf).

RTI. (2013a). "Coconut." from <http://www.ictedge.org/coconut>.

RTI. (2013b). "Malaria Detection." from <http://www.ictedge.org/meeds>.

RTI. (2013c). "Malaria Surveillance." from <http://www.ictedge.org/coconut-surveillance>.

- Rulisa, S., F. Kateera, J. P. Bizimana, S. Agaba, J. Dukuzumuremyi, L. Baas, J. d. D. Harelimana, P. F. Mens, K. R. Boer and P. J. de Vries (2013). "Malaria Prevalence, Spatial Clustering and Risk Factors in a Low Endemic Area of Eastern Rwanda: A Cross Sectional Study." *Plos One* 8(7): e69443.
- Sabot, O., J. Tulloch, S. Basu, W. Dyckman, D. Moonasar and B. Moornen (2009). Getting to Zero. *Shrinking the Malaria Map: A Proscpectus on Malaria Elimination*. R. G. A. Feachem, A. A. Phillips and G. A. Targett, UCSF Global Health Group: 19-40.
- Sackett, D. L., W. M. C. Rosenberg, J. A. M. Gray, R. B. Haynes and W. S. Richardson (1996). "Evidence Based Medicine: What It Is and What It Isn't - It's About Integrating Individual Clinical Expertise and the Best External Evidence." *British Medical Journal* 312(7023): 71-72.
- Sahal, N., R. Reintjes and A. R. Aro (2009). "Review Article: Communicable Diseases Surveillance Lessons Learned from Developed and Developing Countries: Literature Review." *Scandinavian Journal of Public Health* 37(2): 187-200.
- Sanson-Fisher, R. W., E. M. Campbell, A. T. Htun, L. J. Bailey and C. Millar (2008). "We Are What We Do: Research Outputs of Public Health." *American Journal of Preventive Medicine* 35(4): 380-385.
- Schutchfield, F. D. and R. C. Ingram (2013). "Public Health Systems and Services Research: Building the Evidence Base to Improve Public Health Practice." *Public Health Reviews* 35(1).
- Schutchfield, F. D., J. S. Marks, D. J. Perez and G. P. Mays (2007). "Pulic Health Services and Systems Research." *American Journal of Preventive Medicine* 33(2): 98-99.
- Schutchfield, F. D., D. J. Perez, J. A. Monroe and A. F. Howard (2012). "New Public Health Services and Systems Research Agenda: Directions for the Next Decade." *American Journal of Preventive Medicine* 42(5 Suppl 1): S1-5.
- Schwartz, E., H. Pener, S. M. Issa and J. Golenser (1997). "An Overview of the Malaria Situation in Zanzibar." *Journal of Community Health* 22(1): 33-44.
- Sinka, M. E., M. J. Bangs, S. Manguin, Y. Rubio-Palis, T. Chareonviriyaphap, M. Coetzee, C. M. Mbogo, J. Hemingway, A. P. Patil, W. H. Temperley, P. W. Gething, C. W. Kabaria, T. R. Burkot, R. E. Harbach and S. I. Hay (2012). "A Global Map of Dominant Malaria Vectors." *Parasites & Vectors* 5(1): 69.

- Smith, D. L., F. E. McKenzie, R. W. Snow and S. I. Hay (2007). "Revisiting the Basic Reproductive Number for Malaria and its Implications for Malaria Control." PLoS Biology 5(3): e42.
- Snow, R. W. and H. M. Gilles (2002). Essential malariology. Fourth edition.
- Snow, R. W., K. M. Rowan, S. W. Lindsay and B. M. Greenwood (1988). "A Trial of Bed Nets (Mosquito Nets) as a Malaria Control Strategy in a Rural Area of the Gambia, West-Africa." Transactions of the Royal Society of Tropical Medicine and Hygiene 82(2): 212-215.
- Stresman, G. H., A. Kamanga, P. Moono, H. Hamapumbu, S. Mharakurwa, T. Kobayashi, W. J. Moss and C. Shiff (2010). "A Method of Active Case Detection to Target Reservoirs of Asymptomatic Malaria and Gametocyte Carriers in a Rural Area in Southern Province, Zambia." Malaria Journal 9: 265.
- Stroup, D. F. and R. L. Berkelman (1998). History of Statistical Methods in Public Health. Statistics in Public Health: Quantitative Approaches to Public Health Problems. S. D.F. and S. M. Teutsch. New York, Oxford University Press
- Sturrock, H. J. W., M. S. Hsiang, J. M. Cohen, D. L. Smith, B. Greenhouse, T. Bousema and R. D. Gosling (2013). "Targeting Asymptomatic Malaria Infections: Active Surveillance in Control and Elimination." Plos Medicine 10(6): e1001467.
- Sutcliffe, C. G., T. Kobayashi, H. Hamapumbu, T. Shields, S. Mharakurwa, P. E. Thuma, T. A. Louis, G. Glass and W. J. Moss (2012). "Reduced Risk of Malaria Parasitemia Following Household Screening and Treatment: A Cross-Sectional and Longitudinal Cohort Study." Plos One 7(2): e31396.
- TACAIDS, Z., OCGS, and ICF International (2012). Tanzania HIV/AIDS and Malaria Indicator Survey 2011-2012. Zanzibar, National Bureau of Statistics.
- Trei, J. S. and K. M. Carvelli (2008). "Completeness and Timeliness of Chlamydia Trachomatis and Neisseria Gonorrhoeae Genital Infection Reporting in the U.S. Air Force." Mil Med 173(3): 313-317.
- Turnock, B. J. and A. Handler (1995). "Evaluating the Performance of Local Health Agencies. 2. The 10 Public-Health Practices vs the 10 Public Health Service: A Clarification." American Journal of Public Health 85(9): 1295-1296.

- Turnock, B. J., A. S. Handler and C. A. Miller (1998). "Core Function-Related Local Public Health Practice Effectiveness." Journal of Public Health Management and Practice 4(5): 26-32.
- UN. (2000). "Goal 6: Combat HIV/AIDS, Malaria, and Other Diseases." from <http://www.un.org/millenniumgoals/aids.shtml>.
- USAID (1983). Report of the Evaluation of the USAID Zanzibar Malaria Control Project. Washington, D.C., United States Agency of International Development.
- Victora, C. G., J. P. Habicht and J. Bryce (2004). "Evidence-Based Public Health: Moving Beyond Randomized Trials." American Journal of Public Health 94(3): 400-405.
- Vogt, R. L., R. Spittle, A. Cronquist and J. L. Patnaik (2006). "Evaluation of the Timeliness and Completeness of a Web-Based Notifiable Disease Reporting System by a Local Health Department." Journal of Public Health Management and Practice 12(6): 540-544.
- Wagner, M. M., F. C. Tsui, J. U. Espino, V. M. Dato, D. F. Sittig, R. A. Caruana, L. F. McGinnis, D. W. Deerfield, M. J. Druzdzal and D. B. Fridsma (2001). "The Emerging Science of Very Early Detection of Disease Outbreaks." Journal of Public Health Management and Practice 7(6): 51-59.
- Waters, E. and J. Doyle (2002). "Evidence-Based Public Health Practice: Improving the Quality and Quantity of the Evidence." Journal of Public Health Medicine 24(3): 227-229.
- Wernsdorfer, W., S. I. Hay and G. D. Shanks (2009). Learning From History. Shrinking the Malaria Map: A Prespectus on Malaria Elimination. R. G. A. Feachem, A. A. Phillips and G. A. Targett, UCSF Global Health Group: 95-108.
- Wernsdorfer, W. H. (1980). The Importance of Malaria in the World. Malaria: Epidemiology, Chemotherapy, Morphology and Metabolism. J. P. Kreier. 1: 1-93.
- Wernsdorfer, W. H. (2012). "Global challenges of Changing Epidemiological Patterns of Malaria." Acta Tropica 121(3): 158-165.
- White, N. J., S. Pukrittayakamee, H. Tran Tinh, M. A. Faiz, O. A. Mokuolu and A. M. Dondorp (2014). "Malaria." Lancet 383(9918): 723-735.
- WHO (1999). WHO Recommended Surveillance Standards. Second Edition. Geneva, World Health Organization.

- WHO (2000). *New Perspectives Malaria Diagnosis: Report of a Joint WHO/USAID Informal Consultation*. Geneva, World Health Organization.
- WHO (2006). *Communicable Disease Surveillance and Response Systems: Guide to Monitoring and Evaluating*. Geneva, World Health Organization.
- WHO (2007). *Malaria Elimination: A Field Manual for Low and Moderate Endemic Countries*. Geneva, World Health Organization.
- WHO (2012a). *Disease Surveillance for Malaria Control*. Geneva, World Health Organization.
- WHO (2012b). *Disease Surveillance for Malaria Elimination*. Geneva, World Health Organization.
- WHO (2013). *World Malaria Report 2013*. Geneva, World Health Organization.
- WHO (2014). *World Malaria Report 2014*. Geneva, World Health Organization.
- Wongsrichanalai, C., M. J. Barcus, S. Muth, A. Sutamihardja and W. H. Wernsdorfer (2007). "A Review of Malaria Diagnostic Tools: Microscopy and Rapid Diagnostic Test (RDT)." *American Journal of Tropical Medicine and Hygiene* 77(6): 119-127.
- Woolhouse, M. E. J., C. Dye, J. F. Etard, T. Smith, J. D. Charlwood, G. P. Garnett, P. Hagan, J. L. K. Hii, P. D. Ndhlovu, R. J. Quinnell, C. H. Watts, S. K. Chandiwana and R. M. Anderson (1997). "Heterogeneities in the Transmission of Infectious Agents: Implications for the Design of Control Programs." *Proceedings of the National Academy of Sciences of the United States of America* 94(1): 338-342.
- Yangzom, T., C. S. Gueye, R. Namgay, G. N. L. Galappaththy, K. Thimasarn, R. Gosling, S. Murugasampillay and V. Dev (2012). "Malaria Control in Bhutan: Case Study of a Country Embarking on Elimination." *Malaria Journal* 11: 9.
- Yoo, H.-S., O. Park, H.-K. Park, E.-G. Lee, E.-K. Jeong, J.-K. Lee and S.-I. Cho (2009). "Timeliness of National Notifiable Diseases Surveillance System in Korea: A Cross-Sectional Study." *BMC Public Health* 9: 93.
- ZAMEP (2012). *2013-2018 Strategic Plan*. Zanzibar, Ministry of Health and Social Welfare.
- Zeger, S. L., R. Irizarry and R. D. Peng (2006). "On Time Series Analysis of Public Health and Biomedical Data." *Annual Review of Public Health* 27: 57-79.

ZMCP (2009). Malaria Elimination in Zanzibar: A Feasibility Assessment. Zanzibar, Ministry of Health and Social Welfare.