

---

# Evaluation of the Impact of Malaria Control Interventions on All-Cause Mortality in Children Under Five Years of Age in Liberia, 2005–2013

Liberia Malaria Impact Evaluation Group

---

April 2018



**USAID**  
FROM THE AMERICAN PEOPLE

U.S. PRESIDENT'S MALARIA INITIATIVE



# Executive Summary

## BACKGROUND AND OBJECTIVE

Malaria is the leading cause of morbidity and mortality in Liberia, accounting for 42% of outpatient visits and a third of all inpatient deaths [1]. Liberia is classified as hyper- to holoendemic<sup>1</sup> with perennial malaria transmission throughout all parts of the country. Thus, the entire population is at risk for malaria. In 2013, it was reported that there were just under 1.5 million confirmed cases of malaria and 1,200 deaths due to malaria in Liberia [2]. Between 2005 and 2013, the government of Liberia and several international development partners invested extensively in malaria control activities, including insecticide-treated nets (ITNs), indoor residual spraying (IRS) in selected areas, intermittent preventive treatment in pregnancy (IPTp), and prompt and effective malaria case management. This report was co-commissioned by Liberia's Ministry of Health (MOH) and National Malaria Control Program (NMCP) and the US President's Malaria Initiative (PMI) to report on the impact of these investments on morbidity and mortality among children under five years of age during the 2005–2013 period.

## EVALUATION DESIGN

The evaluation was based on a before-and-after assessment, which used a plausibility evaluation design that measured changes in malaria intervention coverage, malaria-related morbidity, and all-cause mortality in children under five years of age (ACCM), while accounting for other contextual determinants of child survival during the evaluation period. ACCM was used as the primary measure of impact. Further analyses investigating the relationship between household ITN ownership and malaria parasitemia were conducted using multiple logistic regression to support the plausibility design.

## DATA SOURCES

Data used in the report mainly come from the following five large population-based household surveys: the 2005 Malaria Indicator Survey (MIS), 2007 Demographic Health Survey (DHS), 2009 MIS, 2011 MIS, and the 2013 DHS. These national survey data are supplemented by data from the NMCP and the Liberia health management information system (HMIS), the 2009 and 2013 Liberia Health Facility Surveys, World Bank data, and country project reports.

## IMPLEMENTATION OF MALARIA CONTROL INTERVENTIONS

Household ownership of at least one ITN<sup>2</sup> increased from 18% to 55% nationwide between 2005 and 2013, with greater improvement observed in rural areas (61% by 2013)

---

<sup>1</sup> Holoendemic is defined as transmission that occurs all year long and hyperendemic is defined as intense transmission, but with periods of no transmission in the dry season.

<sup>2</sup> The 2005 MIS and 2007 DHS estimates are of household ownership of any bednet, neither survey measured ownership of ITNs.

compared to urban areas (50% by 2013). The percentage of the population with “access” to an ITN, defined as the percent of the de facto household population that could sleep under an ITN if each ITN in the household were used by up to two people, rose from 16% in 2007 to 36% in 2013. ITNs were used the night before the survey by 32% of the surveyed population, 38% of children under five years of age, and 37% of pregnant women in 2013. The proportion of households with at least one ITN and/or IRS in the last 12 months reached 59% by the end of the evaluation period; however, most of this was attributed to increased household ITN ownership. Overall, household ownership of one or more ITNs grew steadily during the evaluation period, however household access to an ITN (defined as one ITN for every two people in the household) only reached 22% by 2013.

National household survey data on IRS coverage, only available during the latter part of the evaluation period showed coverage remained stable, ranging from 9–11% between 2011 and 2013. IRS coverage increased in targeted areas between 2009 and 2012, before declining in 2013.

Implementation of IPTp began in Liberia in 2005. Coverage of IPTp (2 or more doses of sulfadoxine-pyrimethamine) increased substantially from 4% in 2005 to just under 50% by 2013, though coverage reached 45% by 2009 and then remained relatively unchanged between 2009 and 2013.

Care-seeking for fever from formal health providers for children under five years of age remained stable during the evaluation period, ranging from 60–70%. Among children under five years of age with fever, treatment with any antimalarial drug also remained relatively unchanged between 2007 and 2013, covering 56% of children in 2013. Treatment with first-line antimalarial drugs (ACTs) however did improve substantially over the evaluation period, increasing from 13% in 2007 to 40% in 2011. A decline was observed in coverage of first-line treatment in 2013, however this is complicated by an issue with recall bias in the 2013 survey and therefore is likely not a true decline.<sup>3</sup>

## MORBIDITY AND MORTALITY TRENDS

### *Morbidity*

Malaria parasitemia prevalence among children 6-59 months measured through rapid diagnostic tests (RDTs) saw a substantial decline from 66% in 2005 to 37% in 2009; but then increased to 45% in 2011. Malaria parasitemia measured through microscopy however showed a slight decline from 32% in 2009 to 28% in 2011 among children 6-59 months of age (no data are available from the beginning of the evaluation period); however due to data quality issues in the 2011 survey, the declining trend should be interpreted

---

<sup>3</sup> The first-line treatment at the time of the 2013 DHS (Artesunate-Amodiaquine) was locally referred to as Amodiaquine, making it difficult to distinguish use of the single drug and the ACT. Fixed dose ACTs were introduced in Liberia in 2010 and Amodiaquine as a monotherapy was no longer procured. Thus it is likely that many of the children who were reported to have taken Amodiaquine in the 2013 DHS actually received an ACT.

with caution. It is important to also note that the 2009 MIS took place during the dry season, while the 2011 MIS was conducted during the rainy season; thus making it difficult to compare trends across these two surveys. The 2005 MIS was conducted in the rainy season, and thus more comparable to the 2011 estimates. Severe anemia prevalence among children 6-59 months of age increased significantly from 5% in 2009 to 8% in 2011; however no other data points were available to better assess the trends over the entire evaluation period.

Data from the HMIS showed that the number of confirmed malaria cases among children under five years of age and people five years of age and above gradually increased between 2009 and 2012, before declining in 2013. The increase observed between 2009 and 2012 however, should be interpreted with caution as it is likely in part due to the increase in health facilities reporting and an increase in the percentage of suspected cases being tested. Overall, trends in malaria parasitemia show an overall decline during the evaluation period, while confirmed malaria cases suggest a decline toward the end of the evaluation period.

### *Mortality*

All-cause child mortality (ACCM)<sup>4</sup> declined by 14% over the evaluation period, from 109 to 94 deaths per 1,000 live births between 2002—2006 and 2009—2013. Annual mortality trends show that ACCM fluctuated over the evaluation period, with no consistent decline observed. When assessing trends in ACCM by age group, the greatest relative decline between the two survey periods was among infants (25%). Declines were observed in all age groups except child mortality (mortality between 12 and 59 months); however, the decline was only significant among infants. ACCM was greater in rural areas in the 2009–2013 period, and greater relative declines were observed in urban areas compared to rural areas between the two survey time periods. Altogether, the data suggest a small decline in ACCM over the evaluation period that was mainly due to a decline in infant mortality.

### *Contextual Factors*

This report includes a comprehensive review of contextual determinants of child survival, which could have contributed to the observed changes in mortality during the evaluation period. Among the social and economic determinants, improvements were seen in access to health facilities and the overall health system infrastructure, GDP per-capita, total health expenditure per capita, women's education and literacy, and household asset ownership (telephones). Furthermore, improvements in a number of maternal and child health interventions were observed during the evaluation time period, including: antenatal care attendance, tetanus toxoid vaccination, delivery at a health facility and with a skilled attendant, immunization coverage, and vitamin A supplementation for children 6-59 months of age. Positive changes were also observed in children's nutrition status, with a substantial increase in exclusive breastfeeding prevalence during the first six months, and statistically significant declines in the prevalence of children under five years of age that are stunted and underweight.

---

<sup>4</sup> The DHS survey estimates for ACCM is measured for the five-year period preceding the survey.

### *Multiple logistic regression analysis*

Multiple logistic regression analyses assessing the association between household ITN ownership with parasitemia prevalence (via RDT) among children 6-59 months of age show a protective effect that just fell short of statistical significance. A second similar model examining the association between household ITN ownership by age of the net and parasitemia prevalence however, showed a significant protective effect on parasitemia prevalence for children living in households that owned an ITN for 0 to 6 months. Both models demonstrated that other variables, including age of the child, region of the country, place of residence, malaria risk, and household wealth to be significantly associated with parasitemia prevalence.

### CONCLUSION

In summary, the findings show that Liberia made progress in expanding coverage of malaria control interventions during the evaluation period, however coverage for all four key interventions remained below the national targets of 80% coverage. Improvements were observed in ITN use among the general population and in children under five years of age and pregnant women (32%, 38%, and 37%, respectively by 2013). Household ITN ownership increased more than three-fold, from 18% in 2005 to 55% by 2013. However, household access to an ITN only reached 22% by 2013, demonstrating a gap in sufficient coverage of ITNs. National IRS coverage remained unchanged between 2011 and 2013 (ranging from 9-11%), but IRS coverage increased in targeted areas during the latter half of the evaluation period (2009–2012). IPTp coverage had the greatest gains, increasing from 4% in 2005 to just under 50% by 2013. ACT treatment coverage of children under five years of age also showed significant improvement between 2007 and 2011.

A significant decline was observed in malaria parasitemia prevalence over the evaluation period; RDT results showed a 21% decrease between 2005 and 2011. HMIS data on malaria cases also suggest a decline occurring at the end of the evaluation period. These declines in malaria morbidity are most likely due to the expansion of malaria control interventions, given there is no evidence of changes in other contextual factors that would have led to the observed declines. ACCM gradually declined during the evaluation period; however the decline was mainly due to a significant decrease in infant mortality – from 71 to 54 deaths per 1,000 live births. Child mortality remained stable during this period, which is not consistent with what we would expect had the expansion of malaria control interventions contributed to a reduction in ACCM. Due to these trends in ACCM and age-specific mortality, it was likely too early in the process of the expansion of malaria control interventions to have observed a significant impact on ACCM. Furthermore, the evaluation period occurred within an overall environment of improvement in the country post-civil war, where the healthcare system was being rebuilt, GDP was rising, and other significant improvements in maternal and child health were taking place. Thus, it is likely that these other factors contributed to the decrease observed in ACCM, and specifically to the decrease in infant mortality, over the evaluation period.

## Acknowledgements

This evaluation was undertaken by the Liberia Malaria Impact Evaluation Group. This group comprises a large number of individuals and institutions who assisted with the planning, methodology, data assembly, data analysis, interpretation, and report preparation. Team members and contributors are listed below.

The team would like to acknowledge the collaboration of the Ministry of Health and the National Malaria Control Program (NMCP) in this evaluation. Particular thanks are extended to Oliver Pratt, Victor S. Koko, D. Levi Hinneh, Joseph O. Alade, Kwabena Larbi, Minister Sanford Wesseh, Stephen Seah, Stephen Gbanyan, and Luke Bawo. A special thanks to Victor S. Koko, who led the coordination of the evaluation for the NMCP. Acknowledgement is also due to the group of malaria and child health stakeholders who provided comments at the stakeholder engagement workshop for the impact evaluation and the stakeholder preliminary findings dissemination meeting (See Annex 4 for the full list of participants).

Key individuals who directed, managed and reviewed multiple versions of the report include (in alphabetical order of organization): Samantha Herrera, Tajrina Hai, and Yazoume Ye (MEASURE Evaluation/ICF International); Victor S. Koko (National Malaria Control Program); Christie Hershey and Rene Salgado (PMI-United States Agency for International Development (USAID)); Ramlat Jose (PMI-USAID, Liberia); Christie Reed (PMI- United States Centers for Disease Control and Prevention (CDC), Liberia); and Sumo Zeze, James Thompson, William Belleh and Forkpa Karmon (Subah-Belleh Associates).

Samantha Herrera (MEASURE Evaluation/ICF International) led the analysis for the evaluation and was the lead author of the report with the assistance from other colleagues of ICF International: Tajrina Hai (data analysis, development of figures and tables, and writing of sections of report) and Yazoume Ye (general advice on analysis and review of report) – MEASURE Evaluation/ICF International, and Lia Florey and Cameron Taylor (general advice on analysis) – DHS Program/ICF International. James Thompson, Sumo Zeze, William Belleh and Forkpa Karmon wrote the country context for the introduction chapter and the background intervention sections.

Thanks are also due to a number of additional members of the Liberia Malaria Impact Evaluation Group, including Christen Fornadel (PMI-USAID), Kaa Williams (PMI-USAID, Liberia), Gabriel Ponce-de Leon (PMI-CDC) and Michael Aidoo (PMI-CDC).

This evaluation was financed by the United States Agency for International Development (USAID) under the US President’s Malaria Initiative.

## Acronyms

ACCM	All-cause mortality of children under five years of age
ACT	Artemisinin-based combination therapy
ANC	Antenatal care
BCG	Bacille Calmette–Guérin (vaccine)
CDC	(United States) Centers for Disease Control and Prevention
CI	Confidence Interval
DHS	Demographic and Health Survey
DTP	Diphtheria, tetanus, pertussis (vaccine)
EPI	Expanded Program on Immunization
GDP	Gross domestic product
GF	Global Fund to Fight AIDS, Tuberculosis and Malaria
Hb	Hemoglobin
HBV	Hepatitis type B vaccine
Hib	Haemophilus influenzae type B vaccine
HMIS	Health management information system
IPTp	Intermittent preventive treatment in pregnancy
IRS	Indoor residual spraying
ITN	Insecticide-treated net
LiST	Lives Saved Tool
LLIN	Long-lasting insecticide-treated net
MIS	Malaria Indicator Survey
MOH	Ministry of Health
MSF	<i>Médecins Sans Frontières</i>
NMCP	National Malaria Control Program
NN	Neonatal mortality (first month), per 1,000 live births
PMI	U.S. President’s Malaria Initiative
PNN	Post-neonatal mortality (age 1-11 months), per 1,000 live births
RBM	Roll Back Malaria Partnership
RDT	Rapid diagnostic test
SP	Sulfadoxine-pyrimethamine
UNICEF	United Nations Children’s Fund
USAID	United States Agency for International Development
WHO	World Health Organization
WN	Weighted number

# Table of Contents

<b>Executive Summary</b> .....	<b>ii</b>
<b>Acknowledgements</b> .....	<b>vi</b>
<b>Abbreviations</b> .....	<b>Error! Bookmark not defined.</b>
<b>Table of Contents</b> .....	<b>viii</b>
<b>Figures</b> .....	<b>xi</b>
<b>Tables</b> .....	<b>xiii</b>
<b>INTRODUCTION AND BACKGROUND</b> .....	<b>1</b>
<b>Purpose and Scope of Evaluation</b> .....	<b>1</b>
<b>Evaluation Design</b> .....	<b>1</b>
<b>Evaluation Indicators</b> .....	<b>2</b>
<b>Data Sources</b> .....	<b>5</b>
<b>Limitations of the Evaluation</b> .....	<b>5</b>
<b>Analytic Plan</b> .....	<b>6</b>
<b>Country Context</b> .....	<b>7</b>
<b>Background</b> .....	<b>7</b>
<b>Health Services</b> .....	<b>8</b>
<b>Malaria in Liberia</b> .....	<b>10</b>
<b>Malaria Control Strategy</b> .....	<b>11</b>
<b>Resources and Inputs</b> .....	<b>14</b>
<b>EXPANSION OF MALARIA CONTROL INTERVENTIONS</b> .....	<b>15</b>
<b>Insecticide Treated Nets (ITNs)</b> .....	<b>16</b>
<b>Background</b> .....	<b>16</b>
<b>ITN Implementation</b> .....	<b>16</b>
<b>ITN Coverage Trends</b> .....	<b>18</b>
<b>ITN Ownership</b> .....	<b>18</b>
<b>Equity in ITN Ownership</b> .....	<b>19</b>
<b>ITN Use</b> .....	<b>21</b>
<b>Equity in ITN Use</b> .....	<b>22</b>
<b>Gaps in ITN Programs</b> .....	<b>23</b>
<b>ITN Summary</b> .....	<b>24</b>
<b>Indoor Residual Spraying (IRS)</b> .....	<b>26</b>
<b>Background</b> .....	<b>26</b>

IRS Implementation .....	26
IRS Coverage .....	27
<b>Intermittent Preventive Treatment in Pregnancy .....</b>	<b>28</b>
Background.....	28
IPTp Policy and Implementation .....	28
Trends in IPTp coverage.....	29
Equity in IPTp.....	30
<b>Malaria Case Management .....</b>	<b>32</b>
Background.....	32
Case Management Policy and Implementation .....	32
Diagnostics .....	33
Malaria Case Management in Children.....	33
Malaria Case Management Summary .....	39
<b>MALARIA MORBIDITY.....</b>	<b>40</b>
<b>Malaria Parasitemia.....</b>	<b>41</b>
Background.....	41
Trends in Malaria Parasitemia .....	41
Equity in Malaria Parasitemia .....	43
<b>Severe Anemia.....</b>	<b>45</b>
Background.....	45
Trends in Severe Anemia.....	45
Equity in Severe Anemia.....	46
<b>Facility-based Malaria Cases Data.....</b>	<b>48</b>
Summary of Malaria Morbidity.....	51
<b>MORTALITY.....</b>	<b>52</b>
Background.....	53
Trends in All-cause Mortality of Children Under Five Years of Age (ACCM) .....	53
Equity in ACCM .....	56
<b>CONTEXTUAL FACTORS.....</b>	<b>59</b>
Accounting for Contextual Factors.....	60
Fundamental Determinants.....	61
Civil war .....	61
Socioeconomic factors.....	61

Weather variability .....	65
Mother’s Education and Marital Status.....	66
Proximate Determinants .....	69
Maternal health.....	69
Child health.....	71
Breastfeeding practices and undernutrition in children and women.....	72
HIV/AIDS among children and women .....	74
<b>Summary of contextual factors.....</b>	<b>75</b>
<b>FURTHER ANALYSES .....</b>	<b>78</b>
<b>Multiple Logistic Regression Analysis .....</b>	<b>79</b>
<b>PLAUSABILITY ANALYSIS AND CONCLUSION.....</b>	<b>84</b>
Coverage of malaria control interventions has improved .....	85
Malaria-related morbidity.....	87
Mortality in children under five years of age .....	87
Contextual factors and the plausibility argument .....	88
Further Analyses .....	89
Conclusion.....	90
<b>REFERENCES.....</b>	<b>92</b>

## Table of Figures

Figure 1: Administrative Map of Liberia .....	7
Figure 2: Distribution of Health Facilities by Type and Ownership .....	9
Figure 3: Distribution of Health Workers (n=5,700) in Liberia, by Type .....	10
Figure 4: Malaria parasitemia prevalence (microscopy) in children under five years of age, by region (2011) .....	11
Figure 5: Malaria Financing (US\$) in Liberia between 2005–2013 .....	14
Figure 6: Household ownership of at least one ITN in Liberia, 2005–2013 .....	18
Figure 7: Percentage of de facto population with “access” to an ITN*, 2007–2013.....	19
Figure 8: ITN use among children under five years of age, pregnant women and the general population, 2005–2011.....	21
Figure 9: Ownership, access, and use of ITNs in Liberia from 2007–2013.....	24
Figure 10: Percentage of households that received IRS and owned at least one ITN and/or received IRS in the last 12 months, 2011–2013 .....	27
Figure 11: Percentage of women (15–49 years) with a live birth 0–2 years prior to survey who received at least one dose of SP and IPTp, 2005–2013.....	30
Figure 12: Percentage of children under five years of age with fever in the two weeks preceding the survey for whom treatment was sought from a health provider and for whom treatment was sought from a health provider within 24 hours of fever onset, 2007–2013.....	34
Figure 13: Percentage of children under five years of age with fever in the two weeks preceding the survey who were treated with any antimalarial drug, with first-line antimalarial drugs, and with first-line antimalarial drugs within 24 hours of fever onset, 2007–2013.....	37
Figure 14: Percentage of children under five years of age with fever in the two weeks preceding the survey that had blood taken from a finger or heel by place of residence and nationally, from 2009– 2013 .....	39
Figure 15: Trends in malaria parasitemia prevalence (RDT) by age group, 2009–2011 .....	42
Figure 16: Trends in malaria parasitemia prevalence (microscopy) by age group, 2009–2011 .....	42
Figure 17: Trends in severe anemia (hemoglobin < 8g/dL) prevalence by age group, 2009–2011 .....	45
Figure 18: Number of confirmed malaria cases among children under five per 1,000 population, 2009–2013 .....	48
Figure 19: Number of confirmed malaria cases among individuals five years and above per 1,000 population, 2009–2013 .....	49
Figure 20: Percent of suspected cases tested among children under five and for those five years of age and above, 2009–2013 .....	49
Figure 21: Number of severe malaria cases among children under five per 1,000 population and percent of inpatient admissions due to severe malaria .....	50
Figure 22: Trends in annual ACCM (1997–2013), Liberia from 2007 and 2013 DHS and IGME Estimates.....	54
Figure 23: Trends in age-specific childhood mortality, Liberia, five-year estimates from the 2007 and 2013 DHS.....	55
Figure 24: Inequalities in ACCM in 2002–2006 and 2009–2013, DHS .....	56
Figure 28: Conceptual framework for the evaluation of the malaria control program .....	60
Figure 29: Trends in GDP per capita and annual estimates of ACCM, Liberia, 1997– 2013.....	62
Figure 30: Average Monthly Temperature and Rainfall in Liberia, 1990–2012 .....	65

Figure 31: 12-Month Weighted Anomaly Standardized Precipitation (WASP) Index, Liberia, 1990–2014 .....	66
Figure 32: Summary of trends in malaria control interventions and ACCM and infant mortality, 2005–2013.....	86

## Tables

Table 1: RBM Core Population-Based Indicators Used in this Report.....	2
Table 2: Administrative Divisions of Liberia – Regions and Counties .....	7
Table 3: Select Population and Health Indicators, Liberia.....	8
Table 4: Milestones in Malaria Control Strategy: Timeline of the roll-out of policies and interventions.....	13
Table 5: Total number of ITNs distributed per year in Liberia from 2005–2013.....	17
Table 6: ITN ownership by socio-demographic factors, 2007–2013.....	20
Table 7: ITN use by children under five years of age by socio-demographic factors, 2009–2013 .....	22
Table 8: ITN use by pregnant women by socio-demographic factors, 2009–2013 .....	23
Table 9: Coverage of indoor residual spraying (IRS) in Liberia from 2004–2013 .....	27
Table 10: IPTp Implementation in Liberia: Number of Pregnant Women Attending at least one and two ANC visits and that Received 1 and 2 doses of SP, 2008-2013.....	29
Table 11: Proportion of women (15–49 years) with live birth 0–2 years prior to survey who received IPTp by socio-demographic factors, 2009–2013 .....	31
Table 12: Malaria Case Management Milestones in Liberia .....	33
Table 13: Percentage of children under five years of age with fever in the two weeks preceding the survey for whom care was sought from a health provider, by socio-demographic factors, 2007–2013.....	36
Table 14: Among children under five with fever in two weeks prior to survey who received any antimalarial drug, proportion receiving each antimalarial drug 2007–2013 .....	38
Table 15: Malaria parasitemia (RDT) in children 6-59 months, by age group, 2009–2011 .....	43
Table 16: Malaria parasitemia (microscopy) in children 6-59 months, by age group, 2009–2011 .....	43
Table 17: Malaria parasitemia (RDT) in children 6-59 months, by background characteristics, 2009–2011.....	44
Table 18: Severe anemia (hemoglobin < 8g/dL) prevalence by age group, 2009-2011.....	46
Table 19: Severe anemia (hemoglobin < 8g/dL) prevalence in children 6-59 months of age, by background characteristics, 2009–2011.....	47
Table 20: Trends in the number of confirmed malaria cases among children under five and for those five years of age and above, adjusted for population size.....	50
Table 21: Age-specific mortality (deaths per 1,000 live births) and relative change in age-specific mortality, Liberia, 0-4 years prior to the survey for 2007 and 2013 DHS .....	55
Table 22: ACCM by sociodemographic characteristics, five-year estimates from the 2007 DHS and 2013 DHS.....	57
Table 23: Household attributes and asset ownership, Liberia, 2007–2013.....	64
Table 24: Education and marital status of women 15-49 years in Liberia, 2007–2013 .....	68
Table 25: Maternal health in Liberia, 2007–2013 .....	70
Table 26: Child health in Liberia, 2007–2013.....	72
Table 27: Breastfeeding and undernutrition in children and women in Liberia, 2007–2013 .....	74
Table 28: Summary of changes in factors that could be associated with ACCM in Liberia, 2007–2013 .....	76
Table 29: Multiple logistic regression model: The effect of ITN ownership on malaria parasitemia (via RDT) in children under five years of age .....	80

Table 30: Multiple logistic regression model: The effect of ITN ownership by age of net on malaria parasitemia (via RDT) in children under five years of age .....82

# INTRODUCTION AND BACKGROUND

# INTRODUCTION

## Purpose and Scope

Malaria exacts a large public health burden in Liberia. It is the leading cause of morbidity and mortality in Liberia, accounting for 42% of outpatient visits and just under 40% of inpatient deaths [1]. The country is classified as hyper- to holoendemic<sup>5</sup> for malaria, with the entire population at risk. Due to the burden caused by malaria, and the extensive funding that has been devoted to malaria control, there is a growing demand from policy-makers, program managers, funding partners, and researchers to measure the extent to which malaria control interventions have made an impact on malaria morbidity and mortality. The objective of this evaluation is to assess the progress in Liberia's malaria control efforts between 2005 and 2013, in particular the country's progress towards achieving its set goals and targets laid out in the 2010-2015 National Malaria Control Strategic Plan and key global goals [3, 4].

The report is co-commissioned by Liberia's Ministry of Health (MOH)/National Malaria Control Program (NMCP) and the US President's Malaria Initiative (PMI), in support of the monitoring and evaluation activities conducted by the Roll Back Malaria Partnership (RBM) and the MOH/NMCP. The main objective of the evaluation is to assess the impact of malaria control interventions, including insecticide-treated mosquito nets (ITNs), indoor residual spraying of insecticide (IRS), intermittent preventive treatment in pregnant women (IPTp) and malaria case management, on malaria morbidity and all-cause mortality in children under five years of age (ACCM), between 2005 and 2013 in Liberia. The report does not aim to present an evaluation of program implementation or effectiveness. However, it does include a detailed description of intervention implementation and sub-national variations in intervention coverage. The evaluation also considers other factors that may have contributed to the mortality trend over the period.

The evaluation focuses on the period 2005–2013 because this is the period over which rapid changes have taken place in malaria control interventions and for which data are available. Since 2005, the NMCP, along with implementing partners, intensified efforts to distribute long-lasting insecticide-treated nets (LLINs) in the country. IRS was also gradually rolled out starting in 2009, though some previously targeted IRS was conducted for internally-displaced people's camps in select counties from 2004–2008. In addition, Liberia adopted and rolled out the artemisinin combination therapy (ACT) artesunate-amodiaquine (AS-AQ) as the first-line drug in 2005. IPTp was also adopted in 2003 and rolled out in 2005.

## Evaluation Design

The evaluation is based on a before-and-after assessment, which uses a plausibility evaluation design that measures changes in malaria intervention coverage, malaria-related

---

<sup>5</sup> Holoendemic is defined as transmission that occurs all year long and hyperendemic is defined as intense transmission, but with periods of no transmission in the dry season.

morbidity, and ACCM while accounting for other contextual determinants of child survival during the evaluation period [5, 6].

This report, therefore describes in detail the trends in malaria control interventions, and changes in malaria morbidity and mortality. The plausibility of a cause and effect relationship is further bolstered if

- the magnitude of impact is consistent with the magnitude of the expansion of intervention coverage and intervention efficacy;
- if the age-pattern of change is consistent with malaria-related morbidity and mortality; and
- if the timing of intervention expansion matches trend change in impact, and if there is an ecological association between malaria risk and the observed impact.

At the national level, the report examines changes in other factors that have the potential to influence changes in malaria-related morbidity and ACCM. These contextual factors include weather, socio-economic factors such as gross domestic product (GDP), education, access to improved water and sanitation, and proximate determinants including access to health services, and other predictors of maternal and child health such as nutrition, immunization, and comorbidities.

The Lives Saved Tool (LiST) model [7] was used to estimate the potential contribution of various health interventions (including, but not limited to malaria control interventions) to the number of lives saved of children under five years of age between 2005 and 2013. The LiST has been used by the malaria community to estimate the number of deaths prevented due to ITN and IPTp scale-up in multiple countries in sub-Saharan Africa [8, 9], but it is important to note that the modeled outputs presented in the report do not contribute to the plausibility argument for this evaluation.

## Evaluation Indicators

The selection and definition of indicators used in this evaluation for national-level analysis was guided by the recommendations of RBM’s Monitoring and Evaluation Reference Group (MERG) shown in Table 1.

**Table 1: Roll Back Malaria core population-based indicators used in this report**

Intervention	Indicator Description
<b>Prevention</b>	
Insecticide-treated mosquito nets (ITNs) and indoor residual spraying (IRS)	Proportion of households with at least one ITN
	Proportion of households with at least one ITN for every two people
	Proportion of population with access to an ITN within their household
	Proportion of population who slept under an ITN the previous night

	Proportion of children under five years old who slept under an ITN the previous night
	Proportion of households with at least one ITN and/or sprayed by IRS in the last 12 months
Prevention and control of malaria in pregnant women	Proportion of pregnant women who slept under an ITN the previous night
	Proportion of women who received intermittent preventive treatment (IPTp) with at least two doses of sulfadoxine-pyrimethamine (SP) for malaria during ANC visits during their last pregnancy
<b>Case Management</b>	
Diagnosis	Proportion of children under five years old with fever in the last 2 weeks who had a finger or heel stick
Treatment	Proportion of children under five years old with fever in the last 2 weeks for whom advice or treatment was sought
	Proportion receiving first line treatment, among children under five years old with fever in the last two weeks who received any antimalarial drugs
	Proportion of children under five years old with fever in last two weeks who received any antimalarial treatment*
	Proportion of children under five years old with fever in last two weeks who received first-line treatment according to national policy within 24 hours from onset of fever*
<b>Impact Measure</b>	<b>Indicator Description</b>
Mortality Indicator	All-cause mortality of children under five years of age (ACCM)
Morbidity Indicators	Malaria Parasitemia Prevalence: proportion of children aged 6-59 months with malaria infection
	Severe Anemia Prevalence: proportion of children aged 6-59 months with a hemoglobin measurement of <8 g/dL

Source: Household Survey Indicators for Malaria Control [9].

\*These indicators are no longer recommended by the RBM MERG but are included here as they are still used to track NMCP targets and/or MDG.

ITNs are one of the principal tools for malaria control. The RBM ITN indicators report on ownership, access, and use of ITNs. ITN ownership and access are household-level indicators, whereas use is measured for the individual. Use at the population level is measured, as is use by the target populations historically at greatest risk of malaria morbidity and mortality – children under five years of age and pregnant women.

IRS is another effective tool for vector control. In sub-Saharan Africa, IRS is most commonly targeted in specific areas and not used at a national scale. IRS coverage is measured

together with household ownership of ITNs to provide a measure of household coverage of at least one of the vector control strategies.

IPTp is another key tool of malaria control programs which is measured by RBM indicators. The World Health Organization (WHO) recommends IPTp in highly endemic countries. IPTp was defined as at least two doses of sulfadoxine-pyrimethamine (SP) after quickening and at least one month apart; however these recommendations have since been updated [10]. As of 2012, the WHO recommends that pregnant women living in areas of moderate to high malaria transmission receive SP at each scheduled antenatal care (ANC) visit, with at least one month between each dose, beginning as early as possible in the second trimester [10].

Proper diagnosis and treatment of malaria cases is essential to malaria control. RBM population-based indicators measure some elements of diagnosis and treatment of malaria; however, facility-based data are often better suited to monitoring trends in malaria case management and are included in this report where available. Population-based surveys do not typically contain data on outcomes from visits to health facilities; thus, the proportion of children with fever receiving diagnostic tests for malaria is measured via a proxy indicator in which receipt of a finger or heel stick is considered an indicator for having had a diagnostic test. Questions on care-seeking behavior for fever in children under five years of age, and of the type and timing of treatment with antimalarial drugs are also included.

The prevalence of malaria parasitemia and severe anemia in children 6-59 months of age are two outcomes examined in this evaluation that lie on the causal pathway between malaria control and child mortality. Malaria parasitemia prevalence is perhaps the most direct measure of malaria burden, but there are challenges to interpreting national estimates to measure success of programs given the focal nature of malaria transmission. Severe anemia, defined as blood hemoglobin levels less than 8 grams per deciliter (dL), is a potential impact measure for total malaria-related disease burden as it is associated with malaria-related mortality and is measurable at the population level; it is also affected less by seasonality than malaria parasitemia [11-13]. For this reason, morbidity analyses in this report are supplemented by longitudinal facility-based data on malaria cases where possible.

In line with RBM-MERG guidance, the principal measure of impact used in this evaluation is ACCM, because malaria-specific mortality cannot be reliably measured in most parts of sub-Saharan Africa with the current sources of data. This measure is preferable to malaria-attributable mortality for a number of reasons, including: the non-availability of national-level, malaria-specific mortality data; concerns about the sensitivity and specificity of the verbal autopsy method for attributing deaths to malaria [14] and the fact that malaria is thought to make an “indirect” contribution to the mortality of children under five years of age that is equivalent to 50%-100% of the mortality that can be directly attributed to malaria [15].

To examine ACCM in Liberia, the impact evaluation team used the direct mortality estimates from the 2007 and 2013 Demographic and Health Survey (DHS) and the corresponding annual ACCM estimates from the UN Inter-agency Group for Child Mortality Estimation (IGME).

## **Data Sources**

No new primary data were collected for this evaluation. The data sources for malaria control intervention coverage indicators and some of the contextual factors are the following population-based surveys: 2005 Malaria Indicator Survey (MIS), 2007 DHS, 2009 MIS, 2011 MIS and 2013 DHS. The 2007 DHS provides a baseline for coverage of household ITN ownership and case management coverage, and for ACCM in Liberia. The 2009 MIS provides baseline estimates of other malaria control interventions, including ITN ownership and use, and IPTp, and for morbidity measures, including parasitemia and severe anemia prevalence. The 2013 DHS provides an endline measure of malaria control interventions and ACCM. In 2005 an MIS was conducted; however, the dataset was not available for secondary analysis. Data from the 2005 MIS report is included in the narrative of the findings sections, when available. Supplementary data sources include the Liberia health management information system (HMIS), the 2009 and 2013 Liberia Health Facility Surveys, World Bank data, and country project reports. Throughout the report, the source of data is clearly cited and caveats on data quality, comparability, and assumptions are indicated. A more detailed description of the data sets, survey methods, sample sizes, and other statistical parameters can be found in the annexes.

## **Limitations of the Evaluation**

There are a few limitations with the evaluation. First, the evaluation relied solely upon secondary data sources, thus was limited by what data was available. For example, for most of the malaria control intervention (ITN ownership, ITN use, IPTp, and IRS) and morbidity indicators (malaria parasitemia and severe anemia), datasets were only available as of 2007, therefore it was not possible to assess their trends from the true baseline when malaria funding began (2005), with the exception of a few indicators from the 2005 MIS report. Second, there are known potential biases and limitations with many of the indicators that are reported and used to estimate intervention coverage, malaria-related morbidity, and ACCM. More detailed information on these potential biases and limitations for each of the indicators is presented within the annexes. Lastly, the availability of the HMIS data presented in the report did not cover the entire evaluation period. HMIS data are available beginning in 2009, however the completeness of the data between 2009 and 2011 is unknown as the HMIS did not capture the number of health facilities reporting during this time period. In 2011, the country's HMIS migrated over to the District Health Information System 2 (DHIS2), with health facilities in the counties adopting the new reporting mechanisms between 2011 and 2013. By 2012, the health facility reporting rate was 85%, and 89% in 2013 [16]. Thus, due to these limitations, trends presented using HMIS data must be interpreted with caution.

## Analytic Plan

Evaluation indicators were tabulated at the national level and stratified by different study domains (e.g., sex, place of residence, wealth quintiles, age groups). Where possible, 95% confidence intervals were calculated for each estimate and used to analyze trends over time.<sup>6</sup> For the mortality analysis, survey data from the 2007 and 2013 DHS were used to generate mortality estimates, using a synthetic cohort life table approach. For this evaluation, estimates were generated for the immediate five-year period preceding each survey and these estimates were compared across the two surveys [17, 18]. Additionally, disaggregated annual mortality estimates were calculated for the two available surveys. Analysis of mortality by year was performed using Kaplan-Meier survival probabilities.

Multiple logistic regression analyses were performed to assess the relationship between malaria parasitemia prevalence and household ITN ownership, and other sociodemographic factors. Lastly, a model-based approach using the LiST was used to predict under-five deaths averted due to the expansion of malaria control interventions. It is important to note that the results from this modeling do not serve as evidence for impact. The model was used to supplement the impact evaluation analysis performed with the survey data. The LiST model links coverage of key maternal and child health interventions with an estimate of each intervention's efficacy, and then predicts the number of under-five deaths averted due to increasing coverage of these interventions.

---

<sup>6</sup> In this report, results are referred to as “significant”, “statistically significant” or that “increased significantly” if the 95% confidence intervals of the particular estimates for each survey year do not overlap.

# Country Context

## Background

Liberia is located along the coast of West Africa. It is bordered by Guinea to the northwest, Côte d'Ivoire to the northeast and east, and Sierra Leone to the west. The country is relatively small and has an estimated population of 4.3 million as of 2013 [19]. The population is young, with approximately 61% of the population below the age of 35. The country is fairly split between urban (47%) and rural (53%). This division shows that there continues to be a rapid rural to urban migration of the population. In 1974, only 29% of the population lived in urban settlements; by 2008, it had risen to 47%. The country is divided into fifteen administrative divisions called counties, and five regions (Table 2 and Figure 1).

**Table 2: Administrative Divisions of Liberia – Regions and Counties**

Region	Counties in Region
Northwestern	Grand Cape Mount, Bomi, Gbarpolu
North-Central	Bong, Nimba, Lofa
South-Central	Montserrado, Grand Bassa, Margibi
South-Eastern A	Sinoe, River Cess, Grand Gedeh
South-Eastern B	Maryland, Grand Kru, River Gee

Source: LDHS 2013

**Figure 1: Administrative Map of Liberia**



Source: LDHS 2013

Liberia has a tropical climate and is generally warm and humid throughout the year. The dry season is from November to April, followed by the rainy season, which typically lasts from May to October. The dusty and dry harmattan (desert winds) blow from the Sahara to

the coast in December, bringing relief from the high humidity. The average annual temperature ranges between 18°C in the northern highlands to 27°C along the coast. The annual rainfall ranges from about 200 cm in the inland areas to as high as 510 cm along the coast; however, it can be irregular, vary in intensity, and generally begins earlier in the coastal areas than in the interior.

In 2003, Liberia emerged from 14 years of civil war that devastated much of the country's infrastructure and economy. Since the war, the economy has been on the recovery, with GDP growth steadily increasing to 8.7% by 2013 [20]. Despite gains made since the civil war, it is still a low-income country that relies heavily on external assistance. In 2013, the gross national income per capita was \$370, which is well below the sub-Saharan Africa average of \$1,638, while GDP (current US\$) was only \$1.951 billion [20]. The World Bank also estimates that approximately 63.8% of the population lives below the national poverty line [20].

Table 3 presents a summary of select population and health indicators for Liberia. The fertility rate is 4.7 [21]. Overall, adult literacy is low, with only 48% of women and 71% of men literate [22]. As of 2013, the life expectancy was 61 and 63 years, for men and women, respectively. Child and maternal mortality are also high in Liberia.

**Table 3: Select Population and Health Indicators, Liberia**

<b>Selected Indicators</b>	<b>Value</b>	<b>Source</b>
Population (in millions)	4.3	UN Population estimate for 2013
Population Structure		Liberia Census 2008
- 0 to 4 years (%)	17.7	
- 5 to 14 years (%)	14.8	
- 15 and over (%)	67.5	
Annual Population Growth Rate (%)	2.1	Census 2008
Population density (per sq. mile)	94	2008 Census
Adult literacy (male/female, %)	71/48	2013 Liberia DHS
Total Fertility rate (%)	4.7	2013 Liberia DHS
Under-5 mortality rate (per 1000)	94	2013 Liberia DHS
Infant mortality rate (per 1000 live births)	54	2013 Liberia DHS
Maternal Mortality Rate (per 100,000 births)	640	WHO/Country Statistics and Global Health Estimates
Life expectancy at birth (male/female)	61/63	WHO estimate for 2013
Malaria		
- Malaria share of Under-5 deaths (%)	22	WHO/World Health Statistics 2015
- Incidence of Malaria in Population (per 100,000)	28,637	WHO/World Health Statistics 2015

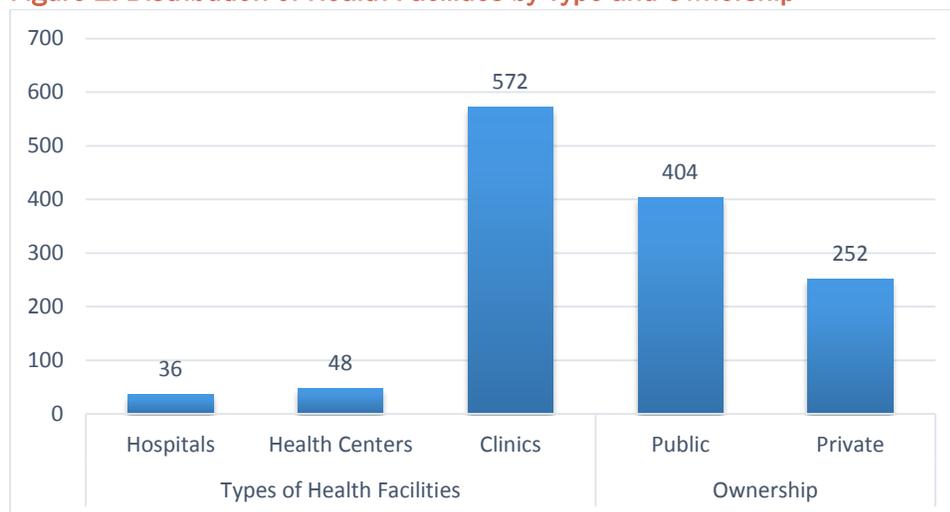
## **Health Services**

Health services in Liberia are classified into three main tiers, based on a referral system. It is a pyramidal structure of health care that includes primary, secondary, and tertiary levels of care [23]. The primary health care level serves a population of approximately 3,500 or less, while the secondary level serves populations over 3,500 within a 5 km radius. Services such as health promotion activities, immunization, and health awareness on hygiene are carried out in communities by community health workers such as Trained Traditional

Midwives and general Community Health Volunteers. According to the MOH’s classification, the primary level of care includes basic health care services delivered through clinics and small health centers, the health clinic being a small facility with not more than five beds and providing basic preventive and curative care, provided mainly at the community level. The secondary level provides a wide range of curative and preventive services, supported by a small laboratory. It includes primary and referral facilities, including county hospitals. At the tertiary level are the John F. Kennedy Medical Center in Monrovia and the Tappita Hospital in Tappita, Nimba County. These are national referral facilities designed to deal with the most complex of medical cases.

The service delivery system is coordinated by the Liberian government, but contains a number of different direct service providers, in addition to government facilities. Other providers include faith-based organizations, local and international NGOs, and the private sector. All of these actors deliver services through 656 facilities across the country, the majority (87.2%) of which are clinics, followed by health centers (7.3%), and hospitals (5.5%). The government is the largest provider of health services, with 62% of the facilities being publicly-owned, compared to the private sector and NGOs, which operate 38% of the facilities (Figure 2). Despite the number of health facilities, an estimated 29% of the population lack access to a health facility within 5 km or 1 hour walk of where they reside and many of the facilities suffer from physical and functional deficiencies. For example, 13% lack access to safe water, 26% do not have a sound structure, 43% do not have a functional incinerator, and 45% do not have a primary power source for emergency lighting [24]. The delivery of health services is decentralized, with county health services managing their own plans, budgets, resources, and administration, with support from the MOH.

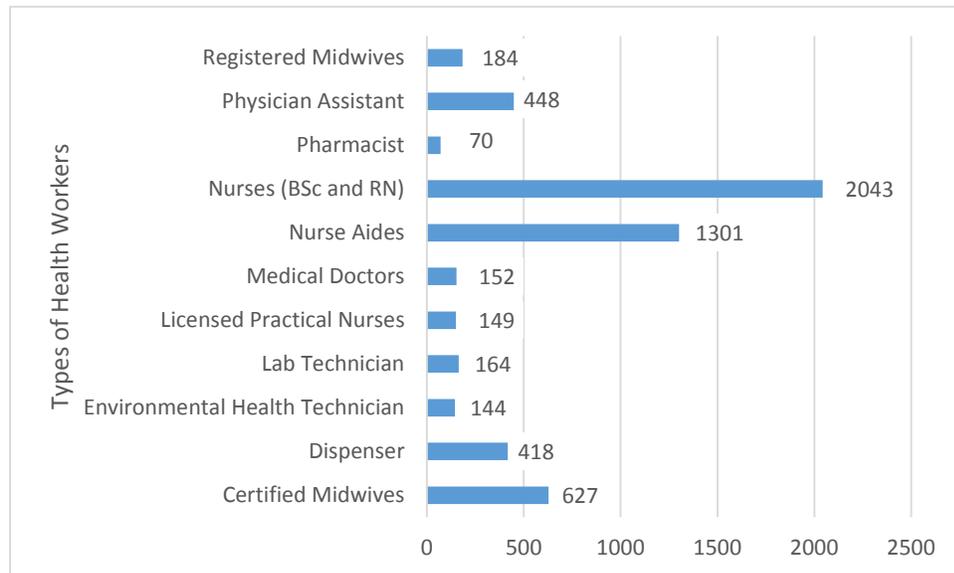
**Figure 2: Distribution of Health Facilities by Type and Ownership**



Source: MOH Health Sector Assessment 2015 [24]

The total health workforce of Liberia is estimated to be 5,700; 36% of whom are nurses, 23% are nurse aides, and 11% are certified midwives (Figure 3). Only 2.7% of the workforce are medical doctors, which translates to 1 doctor for every 28,000 people.<sup>7</sup>

**Figure 3: Distribution of Health Workers (n=5,700) in Liberia, by Type**



Source: MOH Health Sector Assessment 2015 [24]

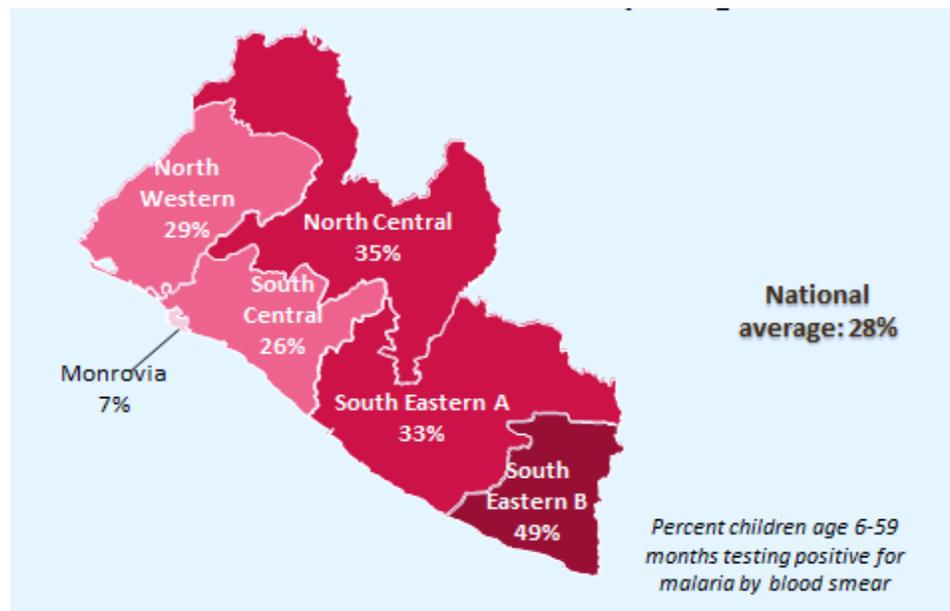
The Liberian health system suffered from many years of dysfunction, due to 14 years of war. However, following the end of the war in 2003, and especially since 2005, real progress was made to rebuild the health system and develop it further, through reforms and the introduction of the Basic Package of Health Services (BPHS) under the 2007-2011 National Health Policy and Plan (now called the Essential Package of Health Services (EPHS) under the current 2011-2021 National Health Policy and Plan) [23, 25]. The EPHS defines the minimum requirements for delivering health services at every level of care in Liberia.

### **Malaria in Liberia**

Malaria is the leading cause of morbidity and mortality in Liberia, accounting for 42% of outpatient visits and a third of all inpatient deaths [1]. Liberia is classified as hyper- to holoendemic to malaria, with perennial transmission. Thus, the entire population is at risk for malaria. In Liberia, the major parasite species is *Plasmodium falciparum* (>90%), followed by *Plasmodium ovale*, and *Plasmodium malariae*. Malaria parasitemia prevalence varies across the geographic regions in the country (Figure 4), with the lowest prevalence in Monrovia (7%) and the highest in the South Eastern B region (49%) [26, 27]. While parasitemia prevalence does vary across the regions, there was not sufficient heterogeneity to produce distinct malaria transmission zones for further analyses in this report.

<sup>7</sup> Based on the UN population estimate of 4.3 million people.

Figure 4: Malaria parasitemia prevalence (microscopy) in children under five years of age, by region (2011)



Source: National Malaria Strategic Plan 2010-2015 (based on 2011 MIS)

In 2012, the annual incidence of malaria was 286 per 1,000 population, while confirmed cases accounted for 24 per 1,000 population in 2014 [28]. In 2013, the under-five mortality rate in Liberia was 94 deaths per 1,000 live births [22]. It is estimated that malaria accounted for 22 percent of all under-five deaths [28].

### Malaria Control Strategy

After the civil war in 2003, the MOH and subsequently, the NMCP was reinstated. In response to the great burden of malaria in the country, a malaria steering committee was developed in 2003 in line with the RBM Partnership to strengthen partnerships and coordination. The main objective of the committee is to advise and guide the NMCP and its implementing partners in their work. In 2004, the MOH introduced a policy for malaria control and prevention. The MOH adopted its First National Malaria Strategic Plan that operated from 2000 to 2005. Since the adoption of the first strategic plan, the NMCP has worked with implementing partners to expand coverage of the four key malaria control and prevention interventions in the country: ITNs, IRS, IPTp, and case management. Two subsequent National Strategic Plans have since been adopted, covering 2005-2010, and the latest from 2010-2015. The Third National Malaria Control Strategic Plan 2010-2015, has as its key objectives to reduce malaria morbidity and mortality by 50% from 2000 levels by 2010 and to halt and begin to reverse the incidence of malaria by 2015, as set out by RBM and WHO. The key strategic framework adopted for achieving these objectives was described as the **Three Ones**: (1) One national malaria control coordinating authority, where implementation is a country-led process; (2) One comprehensive plan for malaria control, including costed work plans; and (3) One country level monitoring and evaluation framework.

This strategic framework supported eight key and broad areas of interventions, designed to achieve the 2010 – 2015 strategic objective:

1. Case Management of malaria with ACT and RDTs at health facility and community level;
2. Management of Malaria in Pregnancy, including IPTp;
3. Integrated Vector Management (IVM), with LLINs, IRS, and other environmental interventions;
4. Advocacy and Behavioral Change Interventions;
5. Strengthened Partnership and Improved Program Management;
6. Operational Research;
7. Monitoring and Evaluation; and
8. Health Systems Strengthening.

#### Key Objectives NMSP 2010 – 2015

- At least 80% of patients with uncomplicated malaria receive early diagnosis and are provided with prompt and effective treatment according to MOH guidelines.
- At least 65% of patients with complicated or severe malaria are timely diagnosed and receive correct treatment according to MOH guidelines.
- 80% of children under five with fever are able to access effective treatment for malaria within 24 hours.
- 80% of health facilities (public or private) carry out malaria diagnostic tests accurately.
- 100% of health facilities have approved, quality anti-malarial drugs available with no stock-out lasting more than 1 week.
- 100% of health facilities are recording accurate data on the diagnosis and treatment of patients with fever.

The different milestones in malaria control policies and implementation over the evaluation period are summarized in Table 4. Details of the implementation of specific malaria control interventions are presented in subsequent sections of this report.

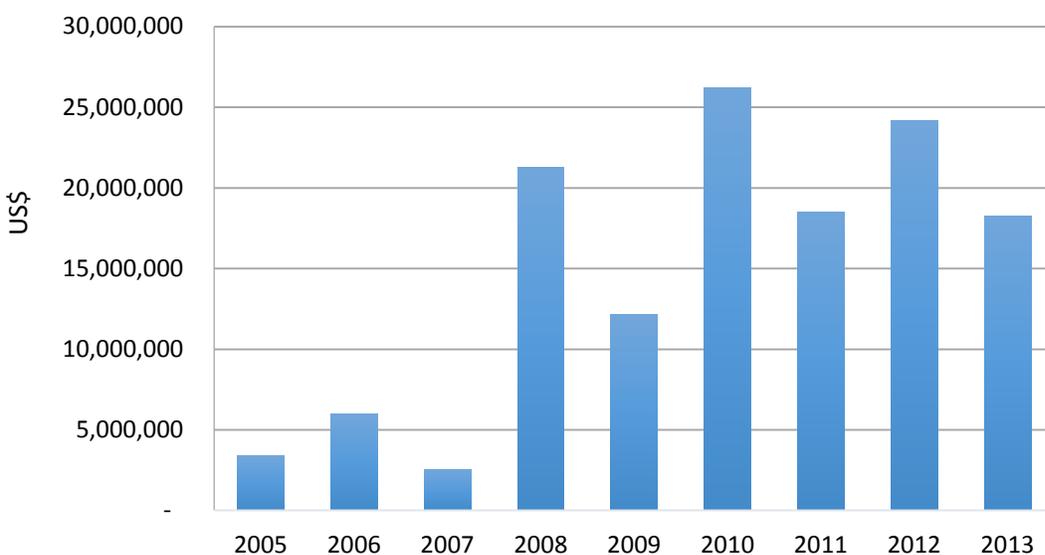
**Table 4: Milestones in Malaria Control Strategy: Timeline of the roll-out of policies and interventions**

Survey	<b>Milestones in Malaria Policy and Implementation</b>	
	2000	<ul style="list-style-type: none"> <li>• First National Malaria Control Strategy (2000–2005) adopted and implemented</li> <li>• Government of Liberia signed the Abuja Declaration.</li> </ul>
	2003	<ul style="list-style-type: none"> <li>• MOH reinstated and the malaria steering committee formed.</li> <li>• <b>IPTp</b>: Policy on IPTp adopted.</li> <li>• <b>ACTs</b> first introduced in Liberia as the first-line treatment for malaria.</li> </ul>
	2004	<ul style="list-style-type: none"> <li>• <b>Case Management, IPTp, ITN, and IRS</b>: First malaria Global Fund grant approved and implemented (2004–2007).</li> <li>• <b>IRS</b>: First implementation of IRS in targeted areas (camps for internally-displaced people in Montserrado and Bong Counties).</li> </ul>
2005 MIS	2005	<ul style="list-style-type: none"> <li>• Second National Malaria Control Strategy (2005–2010) adopted.</li> <li>• <b>IPTp</b>: Implementation of IPTp begins.</li> <li>• <b>Case Management</b>: ACTs officially adopted as the first-line treatment for uncomplicated malaria and rolled out nationally.</li> <li>• <b>ITNs</b>: First distribution of ITNs through ANC and door-to-door distribution.</li> <li>• First MIS conducted.</li> </ul>
	2007	<ul style="list-style-type: none"> <li>• <b>Case Management</b>: RDTs officially introduced in Liberia and rolled out nationally.</li> <li>• National Health Policy adopted, paving the way for the implementation of a basic package of health services (BPHS) that includes malaria control.</li> <li>• 2007 DHS conducted, includes estimates for ACCM.</li> </ul>
2007 DHS	2008	<ul style="list-style-type: none"> <li>• <b>Case Management, IPTp, ITNs, and IRS</b>: Second Global Fund grant approved and implemented. Two funding streams used for the grant, one through UNDP (2008–2011) and one through the MOH (2008–ongoing).</li> <li>• PMI begins implementing malaria prevention and control activities in Liberia.</li> </ul>
	2009	<ul style="list-style-type: none"> <li>• <b>IRS</b>: IRS implementation in dwellings and protected populations begins in two counties (Margibi and Grand Bassa).</li> <li>• <b>ITNs</b>: First rolling mass distribution of LLINs.</li> <li>• Second MIS conducted, includes anemia and parasitemia testing.</li> </ul>
2009 MIS	2010	<ul style="list-style-type: none"> <li>• Third National Malaria Strategic Plan (2010–2015) adopted and implemented.</li> <li>• Integrated Community Case Management (iCCM), Private Sector ACT, Research, and Supply Chain Management units in the NMCP established.</li> </ul>
	2011	<ul style="list-style-type: none"> <li>• Third MIS conducted, includes anemia and parasitemia testing.</li> <li>• <b>Case Management, IPTp, ITNs, and IRS</b>: Third Global Fund grant approved and implemented (2011–ongoing).</li> <li>• Liberia adopts and begins implementation of Essential Package of Health Services (EPHS) which expands on the services offered under the BPHS. Malaria control remains a key component of the EPHS.</li> </ul>
2011 MIS	2012	<ul style="list-style-type: none"> <li>• Liberia adopts the T3 <i>Test. Treat. Track</i> policy requiring a positive RDT before providing treatment.</li> </ul>
	2013	<ul style="list-style-type: none"> <li>• 2013 DHS conducted, includes estimates for ACCM.</li> </ul>
2013 DHS		

## Resources and Inputs

The main sources of funding for the Liberia NMCP include the Global Fund, PMI, and the Liberian Government. Figure 5 presents the distribution of external malaria funding over the evaluation period from the two main donors. Global Fund's contribution began in 2004 with its first grant of \$11.8 million [29]. Three additional grants have been provided to Liberia, two of which are still ongoing (as of 2016). Across the evaluation period, Global Fund provided over \$52.3 million for malaria control activities in Liberia [29]. PMI-supported activities in Liberia began in 2007 with a jumpstart fund of \$2.5 million, before regular annual commitments began in 2008 [30]. Over the evaluation time period, PMI's total funding for malaria prevention and control in Liberia was \$82.3 million [30]. Within this period, donor funds have supported the procurement and distribution of malaria related commodities including LLINs, ACTs, SP, rapid diagnostic tests (RDTs) and insecticides for IRS. Funding has also been provided for technical support to the NMCP, for training of health care workers in malaria case management, monitoring and evaluation activities, and other health system strengthening activities. The Government of Liberia has contributed through the support of the NMCP staff and health care workers and other operational costs. To demonstrate its commitment, the government has steadily increased its domestic funding for malaria control by increasing the salaries of health professionals who spend approximately 30% of their time managing malaria cases, by providing partial tax exemption on all public malaria products and commodities, and maintaining free diagnostic testing and treatment services for malaria at all of its facilities [16, 31].

Figure 5: Malaria Financing (US\$) in Liberia between 2005–2013



# **EXPANSION OF MALARIA CONTROL INTERVENTIONS**

## **Insecticide Treated Nets (ITNs)**

### **Background**

ITNs are a highly effective tool for the prevention of malaria both through direct and indirect insecticidal effects, and reducing contact between vector and humans, therefore lowering parasite loads at the community level [32-34]. Use of ITNs has been found to reduce child mortality [35], lower the risk of clinical malaria illness, reduce parasite prevalence, and reduce the risk of high-density malaria parasitemia [36]. ITN use also reduces the prevalence of severe anemia and splenomegaly and may improve anthropometric outcomes in children [37]. ITN use by pregnant women has been shown to reduce placental malaria, improve birth weight, and reduce fetal loss and stillbirth [38, 39]. The protective effects of ITNs are most pronounced in high transmission settings in children under two years of age and in pregnant women, both of whom have limited immunity to malaria [40, 41].

### **ITN Implementation**

ITN distribution began in Liberia in 2005, and progressively increased over the evaluation period up through 2012 (Table 5). Between 2005 and 2008, the distribution strategy targeted the highest risk groups (pregnant women and children), with ITNs distributed predominantly through antenatal care (ANC) and through door-to-door distribution in targeted areas. In 2009, distribution increased to 812,708 ITNs and the NMCP's strategy shifted from targeting the highest risk groups to universal coverage and ensuring there were sufficient ITNs to cover all the sleeping spaces within a household. Between 2010 and 2011, ITN distribution remained at similar levels as 2009; however, the ITN distribution strategy shifted in 2010 to focus on providing three ITNs per household. The largest distribution of ITNs occurred in 2012 (just under 1 million), before ITN distribution fell to 100,000 in 2013. Between 2011 and 2013, the NMCP's strategy still was focused on achieving universal coverage, but a renewed focus was on promoting continued use of the ITNs distributed through the 'hang-up keep-up' strategy. During the nine-year period, over 5.5 million ITNs were distributed. The greatest number of ITNs distributed between 2005 and 2013 was in the South Central region (over 2.1 million), followed by the North Central region (over 1.7 million). From 2009, ITNs were mainly distributed through rolling mass campaigns, with some additional distribution through institutional delivery targeting pregnant women attending ANC clinics.

**Table 5: Total number of ITNs distributed per year in Liberia from 2005–2013**

Regions of Distribution	Number of ITNs Distributed									
	2005	2006	2007	2008	2009	2010	2011	2012	2013	Total
<i>North Central</i>	170,978	84,267	69,191	212,400	298,000	17,100	310,800	549,483	0	1,712,219
<i>South Central</i>	211,397	46,000	65,100	32,000	349,913	850,490	170,900	357,935	100,000	2,156,721
<i>South Eastern A</i>	38,534	20,261	16,636	133,000	61,087	4,500	165,200	0	0	1,538,218
<i>South Eastern B</i>	7,421	41,472	34,053	116,200	49,300	6,900	139,800	0	0	395,146
<i>North West</i>	21,670	0	31,920	197,000	54,408	4,410	43,300	88,194	0	590,902
<i>Total Distributed</i>	<b>450,000</b>	<b>192,000</b>	<b>216,900</b>	<b>690,600</b>	<b>812,708</b>	<b>883,400</b>	<b>830,000</b>	<b>995,612</b>	<b>100,000</b>	<b>5,574,608</b>
<i>Distribution Strategy</i>	<i>ANC institutional delivery and door-to-door distribution</i>				<i>According to sleeping spaces</i>	<i>3 ITNs per household</i>	<i>Hang-up keep-up</i>			
<b>Source:</b> National Malaria Control Program (NMCP), Plan International										

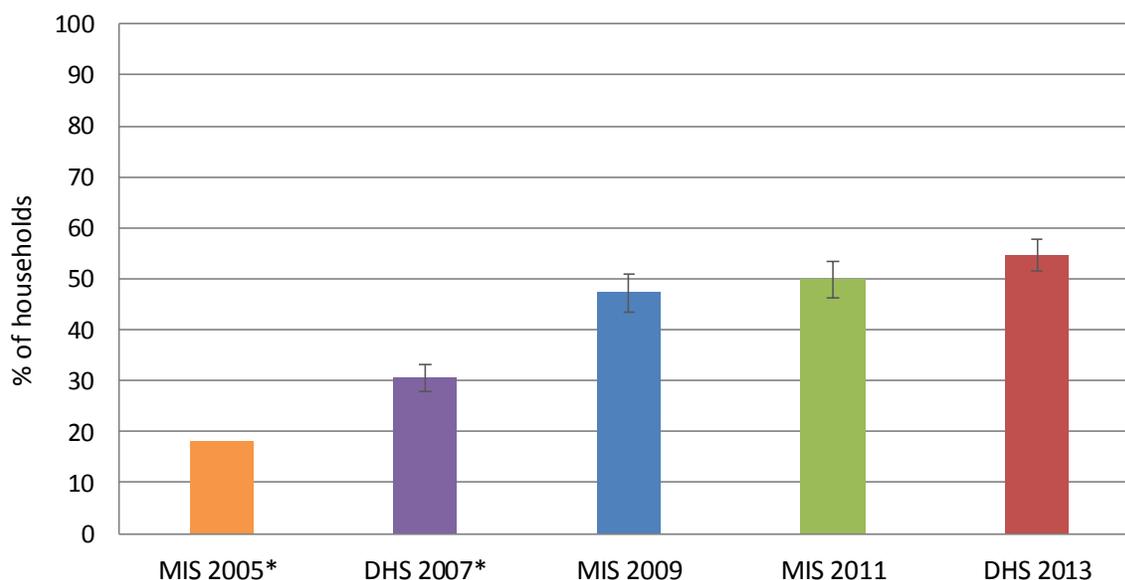
## ITN Coverage Trends

ITN coverage trends are described below using two main indicators: household ITN ownership and ITN use by target groups. The combined ITN and/or IRS coverage indicator is presented under the IRS section. Unless otherwise stated, all data cited come from the 2007 DHS, 2009 MIS, 2011 MIS, and 2013 DHS surveys. The 2007 DHS measured household ownership of any bednet and not ITN ownership specifically.

### ITN Ownership

Figure 6 shows the percentage of households that owned at least one ITN<sup>8</sup> in 2007, 2009, 2011, and 2013. Overall, coverage of ITN household ownership increased gradually during this time period. The percentage of households that owned at least one ITN increased significantly from 30% (95% CI: 28–33%) in 2007 to 55% (95% CI: 51–58%) in 2013. The 2005 MIS reports that household ownership of at least one bednet was 18%.

Figure 6: Household ownership of at least one ITN in Liberia, 2005–2013



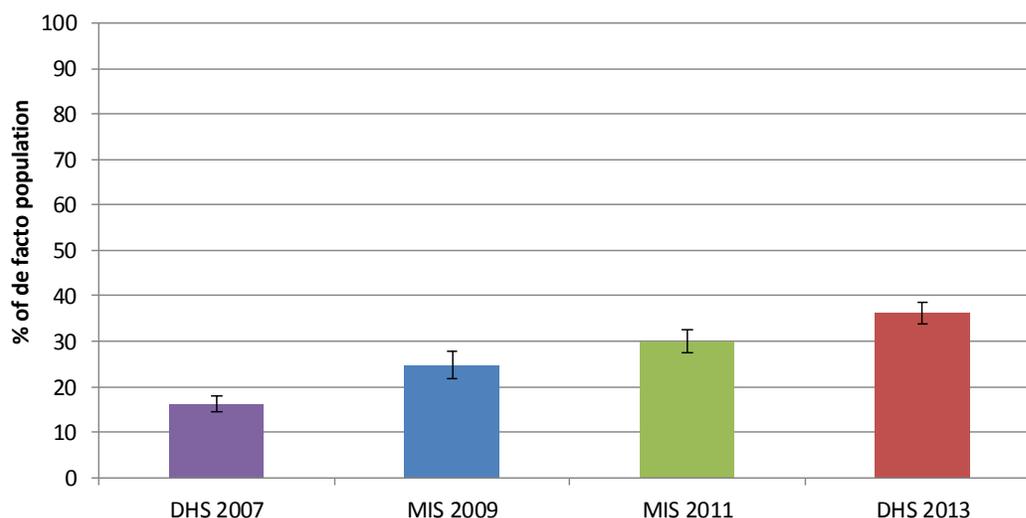
\*The 2005 MIS and 2007 DHS surveys measured household ownership of any net.

Figure 7 shows the percentage of the de facto population (persons who spent the night before the interview in the household) with “access” to an ITN from 2007 to 2013. Access to an ITN is defined as the proportion of the de facto population who could sleep under an ITN, assuming each ITN in the household is used by no more than two people. As with ITN household ownership, access to an ITN increased significantly from 16% (95% CI: 15–18%) in 2007 to 36% (95% CI: 34–38%) in 2013.<sup>9</sup>

<sup>8</sup> In the 2007 DHS survey, this is household ownership of any bednet, as ITN ownership was not measured.

<sup>9</sup> For the 2007 DHS, any bednet access was measured since data on ITN ownership was not available.

Figure 7: Percentage of de facto population with “access” to an ITN\*, 2007–2013



\*Access is defined as the proportion of the de facto household population who could sleep under an ITN if each ITN in the household is used by two people. In the 2007 DHS survey, the estimate reflects access to a bednet, since ITN ownership was not measured in the survey.

### Equity in ITN Ownership

Table 6 presents data on household ownership of at least one ITN by place of residence and wealth quintile<sup>10</sup> across the four survey years. In 2007, 2009, and 2011, no significant differences were found in ITN ownership by place of residence, however in 2013, ITN ownership was significantly higher in rural areas (61%) compared to urban areas (50%). No consistent trend in ITN ownership by wealth quintile was found across the survey years. In 2007, ITN ownership was significantly higher in the least poor households (42%) compared to the poorest households (22%). In 2009 however, ITN ownership was higher overall in poorer households (first three wealth quintiles) compared to those from the least poor households (last two wealth quintiles). In 2011, household ITN ownership was relatively similar across the different wealth quintiles but was significantly lower in the poorest households (41%) compared to the least poor households (54%). By 2013, ITN ownership was the lowest in the least poor households (43%) compared to households in the other wealth quintiles. Overall from 2007 to 2013, ITN household ownership increased the greatest in the households in rural areas and from the poorer wealth quintiles (wealth quintile 1, 2, and 3) and least in the households in urban areas and from the wealthiest quintiles.

<sup>10</sup> The Demographic and Health Surveys wealth index categorizes households into five wealth quintiles. The index is a composite measure of a household’s cumulative living standard, and is calculated based on a household’s ownership of selected assets, materials used for housing construction, and type of water access and sanitation facilities.

Table 6: ITN ownership by socio-demographic factors, 2007–2013

Background Characteristics	2007 DHS*		2009 MIS		2011 MIS		2013 DHS		Percentage point change 2007 to 2013
	% (95% CI)	WN							
<b>Residence</b>									
Urban	31.3 (27.6-35.2)	2,486	42.0 (37.1-47.1)	1,940	52.2 (47.2-57.1)	2,058	49.7 (45.0-54.4)	5,289	18.4
Rural	29.9 (26.3-33.9)	4,338	51.8 (45.8-57.7)	2,222	47.2 (42.0-52.5)	2,104	61.1 (57.7-64.4)	4,044	31.2
<b>Wealth</b>									
Lowest	21.8 (17.6-26.5)	1,466	48.0 (38.9-57.2)	903	40.6 (35.1-46.4)	886	53.1 (49.3-56.9)	2,008	31.3
Second	27.4 (22.6-32.7)	1,412	54.5 (47.0-61.8)	860	53.4 (46.2-60.4)	851	64.2 (60.4-67.8)	1,785	36.8
Middle	32.4 (28.3-36.8)	1,331	52.6 (46.0-59.1)	785	49.2 (42.7-55.7)	784	61.2 (56.5-65.7)	1,738	28.8
Fourth	30.1 (25.7-34.8)	1,357	42.9 (36.7-49.4)	811	52.3 (46.5-58.0)	867	51.8 (46.1-57.6)	2,024	21.7
Highest	42.4 (37.5-47.4)	1,258	37.7 (31.3-44.7)	803	53.5 (46.8-60.1)	774	43.4 (37.7-49.3)	1,777	1.0
<b>Total</b>	30.4 (27.8-33.3)	6,824	47.2 (43.5-51.0)	4,162	49.7 (46.1-53.3)	4,162	54.6 (51.4-57.8)	9,333	24.2

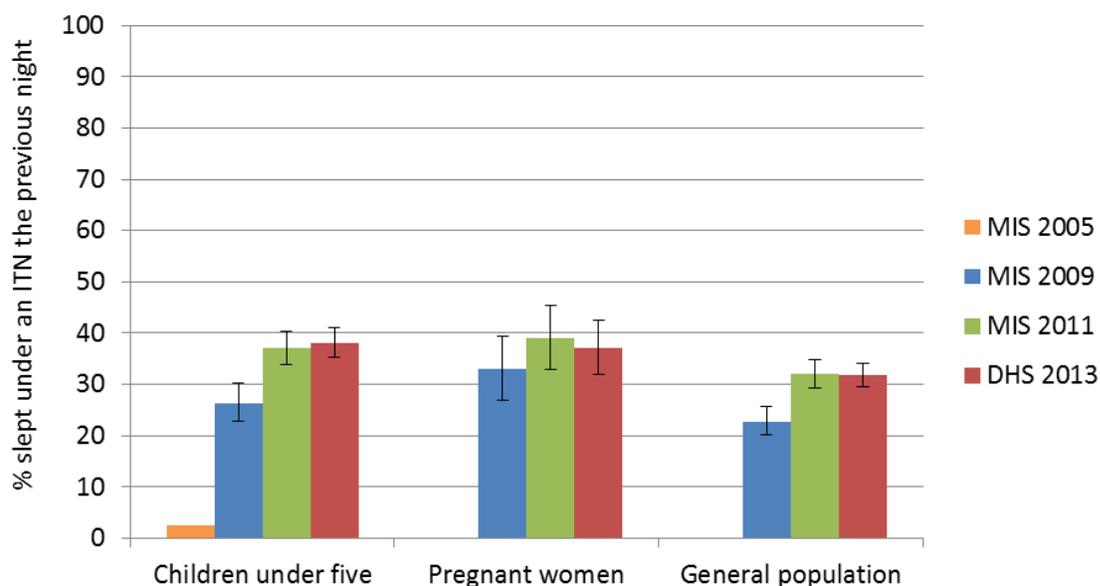
Notes: \*The 2007 DHS measured household ownership of at least one bednet, no information was gathered on household ITN ownership.

## ITN Use

Figure 8 shows ITN use among children under five years of age, pregnant women, and the general population during the time period 2009 to 2013. No data on ITN use was available from the 2007 DHS survey. ITN use was measured among all the households surveyed and among those who slept in the household the night before the interview. Among children under five years of age, use of ITNs the night before the survey rose significantly from 26% (95% CI: 23–30%) in 2009 to 38% (95% CI: 35–41%) by 2013. The 2005 MIS reports<sup>11</sup> that only 2% of children under five years of age used an ITN the previous night, demonstrating a significant increase over the evaluation period. For pregnant women, ITN use remained relatively stable from 2009 to 2013; increasing slightly from 33% (95% CI: 27–40%) in 2009 to 37% (95% CI: 32–43%) in 2013. For the general population as a whole, ITN use rose significantly from 24% (95% CI: 21–26%) in 2009 to 32% (95% CI: 29–35%) in 2011, and then remained steady at 32% in 2013 (95% CI: 30–34%).

ITN use in households that own at least one ITN was significantly higher in children under five years of age, pregnant women, and the general population (data not shown). Among children under five years of age living in households with at least one ITN, ITN use increased significantly from 52% (95% CI: 47–55%) in 2009 to 63% (95% CI: 60–66%) in 2013. Among pregnant women, ITN use increased from 63% (95% CI: 55–71%) in 2009 to 77% (95% CI: 70–84%) in 2011, and declined to 63% (95% CI: 57–69%) in 2013 in households that own at least one ITN. ITN use among the general population (living in households with at least one ITN) increased from 46% (95% CI: 43–49%) in 2009 to 56% (95% CI: 54–58%) in 2013.

**Figure 8: ITN use among children under five years of age, pregnant women and the general population, 2005–2011**



<sup>11</sup> Because the 2005 MIS dataset was not available for further analyses, the confidence interval was not computed

## Equity in ITN Use

Table 7 presents data on ITN use for children under five years of age stratified by sex, place of residence, wealth, and mother's education for 2009, 2011, and 2013. There were no significant differences observed in ITN use among children by sex, place of residence, or mother's education level. The percentage of children that used an ITN the previous night from the poorest households did not vary significantly from those from wealthier households across all three survey years; in 2013 however, ITN use among children from the least poor households was lower overall compared to children from the other wealth quintiles and was significantly lower than children from households in the second and third wealth quintiles. Overall, no significant disparities were observed in ITN use in children under five years of age across the evaluation period; with the exception of 2013, where ITN use was generally higher among children from poorer households compared to children from the wealthier households.

**Table 7: ITN use by children under five years of age by socio-demographic factors, 2009–2013**

Background Characteristic	2009 MIS		2011 MIS		2013 DHS		Percentage point change 2009 to 2013
	% (95% CI)	WN	% (95% CI)	WN	% (95% CI)	WN	
<b>Sex</b>							
Male	25.8 (22.2-29.8)	2,413	36.7 (33.3-40.1)	1,719	38.7 (35.5-42.1)	3,767	12.9
Female	27.1 (23.1-31.4)	2,312	37.5 (33.5-41.6)	1,633	37.4 (34.1-40.7)	3,494	10.3
<b>Residence</b>							
Urban	24.0 (19.4-29.3)	1,796	40.2 (35.1-45.5)	1,377	36.7 (32.1-41.4)	3,617	12.7
Rural	27.9 (23.0-33.4)	2,930	34.8 (30.9-39.0)	1,974	39.5 (35.8-43.2)	3,645	11.6
<b>Wealth</b>							
Lowest	25.6 (18.7-34.0)	1,116	31.7 (26.6-37.2)	863	33.8 (29.9-38.1)	1,752	8.2
Second	34.3 (27.1-42.4)	1,080	41.7 (35.4-48.3)	793	42.0 (37.6-46.6)	1,626	7.7
Middle	24.5 (18.3-32.1)	985	36.0 (29.6-42.9)	652	46.7 (41.7-51.8)	1,514	22.2
Fourth	22.6 (16.6-30.1)	900	41.8 (35.1-48.8)	574	37.0 (31.5-42.9)	1,330	14.4
Highest	22.8 (17.5-29.1)	645	34.8 (27.4-43.0)	470	27.8 (21.4-35.3)	1,040	5.0
<b>Mother's Education</b>							
None	31.5 (27.1-36.1)	1,801	34.1 (29.6-38.8)	1,096	40.4 (35.5-45.5)	1,333	8.9
Primary	29.0 (24.4-34.1)	1,040	39.2 (33.2-45.5)	703	36.1 (30.3-42.2)	918	7.1
Secondary or higher	25.9 (20.5-32.2)	666	41.8 (35.8-48.0)	494	38.6 (32.1-45.4)	872	12.7
Missing	17.1 (12.8-22.5)	1,211	36.5 (32.1-41.2)	1,060	37.7 (34.6-40.9)	4,138	20.6
<b>Total</b>	26.4 (22.9-30.3)	4,725	37.1 (33.9-40.3)	3,352	38.1 (35.2-41.1)	7,261	11.7

Table 8 presents data on ITN use for pregnant women stratified by place of residence, wealth, and mother's education. There were no significant differences in ITN use among pregnant women by place of residence or education level. ITN use among pregnant women from the least poor households was overall lower across all survey years compared to pregnant women from the poorer wealth quintiles. ITN use among pregnant women from

the least poor households slightly declined from 2009 to 2013 and by 2013, was significantly lower (17%) compared to women from households in the other four wealth quintiles.

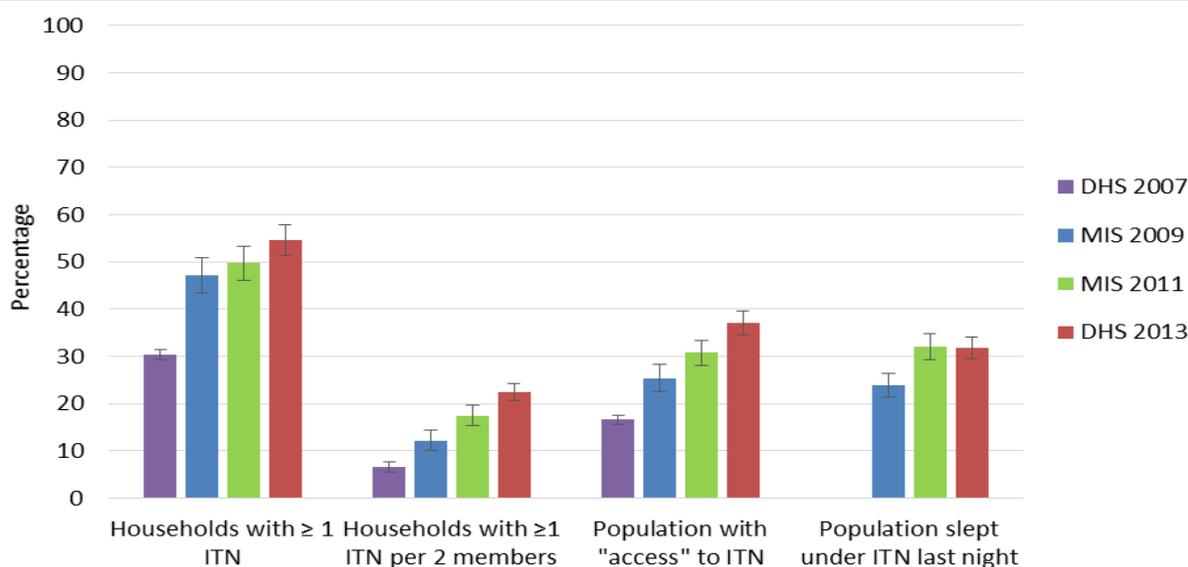
**Table 8: ITN use by pregnant women by socio-demographic factors, 2009–2013**

Background Characteristic	2009 MIS		2011 MIS		2013 DHS		Percentage point change 2009 to 2013
	% (95% CI)	WN	% (95% CI)	WN	% (95% CI)	WN	
<b>Residence</b>							
Urban	29.3 (21.3-38.8)	204	39.3 (29.3-50.3)	160	34.0 (26.5-42.4)	422	4.7
Rural	35.6 (26.9-45.5)	268	38.8 (31.6-46.6)	203	40.3 (34.2-46.9)	394	4.7
<b>Wealth</b>							
Lowest	29.9 (18.3-44.9)	113	37.6 (27.5-49.0)	85	32.0 (25.2-39.7)	173	2.1
Second	35.5 (24.1-48.7)	99	47.2 (37.8-56.8)	87	45.9 (37.7-54.4)	185	10.4
Middle	46.9 (34.5-59.7)	98	39.3 (27.3-52.7)	71	38.7 (29.8-48.4)	184	-8.2
Fourth	27.5 (18.0-39.7)	101	39.5 (24.8-56.5)	63	52.1 (36.3-67.5)	128	24.6
Highest	20.5 (10.6-35.9)	60	27.7 (17.0-41.9)	58	16.5 (7.3-33.3)	146	-4.0
<b>Education level</b>							
None	38.7 (29.6-48.4)	219	38.8 (30.5-47.9)	130	38.4 (30.4-47.2)	304	-0.3
Primary	29.0 (20.8-38.4)	156	37.2 (26.8-48.9)	126	35.7 (28.5-43.4)	290	6.7
Secondary or higher	24.8 (13.7-39.9)	92	41.5 (30.8-52.9)	108	37.0 (28.4-46.5)	222	12.2
<b>Total</b>	32.9 (26.9-39.5)	471	39.0 (33.0-45.4)	363	37.1 (32.0-42.5)	816	4.2

### Gaps in ITN Programs

Examining a cascade of four RBM-recommended ITN indicators can help NMCPs gain insight on gaps in their vector control programs. For example, Figure 9 demonstrates that although ITN ownership steadily increased over the evaluation period to 55% of households owning one or more ITN by 2013, only 22% of households had enough ITNs to cover all household members (at least one ITN per two people). The gap between the percent of the population with access to an ITN and the percent that used an ITN the previous night grew slightly in 2013; in 2009 and 2011 there was very little difference between population access to an ITN and population use of ITNs.

Figure 9: Ownership, access, and use of ITNs in Liberia from 2007–2013



### ITN Summary

Between 2005 and 2013, household ITN ownership increased significantly from 18% in 2005<sup>12</sup> to 55% in 2013. No significant differences in household ownership of ITNs by place of residence were observed in 2007. However, by 2013, ITN ownership was significantly higher in rural areas (61%) compared to urban areas (50%). Overall, ITN ownership increased the greatest from 2007 to 2013 in households from the poorer wealth quintiles (quintiles 1-3), compared to those from the wealthier quintiles (quintile 4 and 5). Household access to an ITN increased during this same period, from 16% in 2007 to 36% in 2013. The rise in household ITN ownership from 2007 to 2013, was accompanied by an increase in ITN use among the general population, from 24% in 2009 to 32% in 2013. ITN use also increased significantly among children under five years of age from 26% to 38% during this same time period; while ITN use among pregnant women remained stable from 2009 to 2013 (33% to 37%). ITN use was much higher in households with at least one ITN across all three populations; however only small increases in use were observed from 2009 to 2013.

No significant differences were found in ITN use among children under five years of age by sex, place of residence, or mother's education level. Similarly for pregnant women, no significant differences were observed in ITN use by place of residence or education level. ITN use in children under five years of age and among pregnant women was overall lower in the least poor households compared to poorer households in 2013.

Overall, household ownership of one or more ITNs improved during the evaluation period; however household access to an ITN (defined as one ITN for every two people in the

<sup>12</sup> 2005 figure is based on household ownership of at least one bednet.

household) only reached 22% by 2013. ITN use showed a small improvement over the evaluation period. While improvements in ITN ownership and ITN use among the general population, children under five years of age, and pregnant women were observed, coverage levels remain well below the national targets of 85% of households owning at least one ITN and 80% ITN use across the three populations.

## Indoor Residual Spraying (IRS)

### Background

In 2006, WHO reaffirmed their recommendation for IRS with insecticides for malaria control in sub-Saharan Africa. A total of four insecticide classes are currently available for IRS [42]. A recent meta-analysis of thirteen IRS studies in sub-Saharan Africa suggests that use of IRS effectively reduces the prevalence of malaria parasitemia in a community by 62% [43]. Despite its apparent effectiveness, few if any countries in sub-Saharan Africa use IRS at a national scale, as costs are often an impediment [44]; nonetheless, in 2009, IRS conferred vector control protection to 10% of the population of Africa [45].

### IRS Implementation

The history of IRS in Liberia dates back to the late 1950s when UNICEF and WHO sponsored a malaria eradication pilot program in the central province of the country to assess if transmission could be interrupted with the insecticide dichlorodiphenyltrichloroethane. The pilot succeeded, however, the program was not scaled up in the country because of high population movement and lack of trained spray personnel, equipment, and facilities to support the program [46]. IRS was reintroduced in 2004 and until 2008 was targeted exclusively in camps for internally displaced people in Bong and Montserrado Counties located in the North and South Central regions, respectively [27]. These camps were set up to accommodate people who had to flee their homes and communities or were forced out of their homes due to the civil war. During this period, no dwelling units<sup>13</sup> were targeted.

In 2009, the use of IRS expanded to cover dwelling units and protected populations, with residents in Mamba Kaba (Margibi County) and Owensgrove #1 (Grand Bassa County) being the first beneficiaries. As shown in Table 9, over 20,000 dwelling units and an estimated 163,149 persons benefitted in the two locations. The second round of IRS in 2010 expanded to include the following additional counties: Careysburg (Montserrado County) and ArcelorMittal Yekepa Camp (Nimba County). A total of 48,375 dwelling units were sprayed, benefitting around 420,532 residents. In 2011, a third round of IRS was carried out, with an estimated 110,427 households and 834,671 residents covered, almost doubling the population reached the previous year. Communities in Kokoyah (Bong County), Kpahi (Bong County), Panta (Bong County), Foumah (Bong County), Mamba Kaba (Margibi County), Careysburg (Montserrado County), Owensgrove #1 (Grand Bassa County), and ArcelorMittal Yekepa Camp (Nimba County) benefitted. Close to 97,000 dwelling units and nearly 870,000 residents in 14 districts in Grand Bassa, Margibi, Montserrado, Bong, and Nimba Counties were reached with carbamate and pyrethroid insecticides in 2012. In 2013, only seven districts in Bong County were reached, with 42,708 dwelling units and close to 368,000 residents covered, due to a switch to a more

---

<sup>13</sup> A dwelling unit, also known as a housing unit, is defined as a place of abode or residence occupied by one or more households with a private entrance.

expensive insecticide (Organophosphates) as a result of insecticide resistance. A summary of IRS implementation from 2005 to 2013 is provided in Table 9.

**Table 9: Coverage of indoor residual spraying (IRS) in Liberia from 2004–2013**

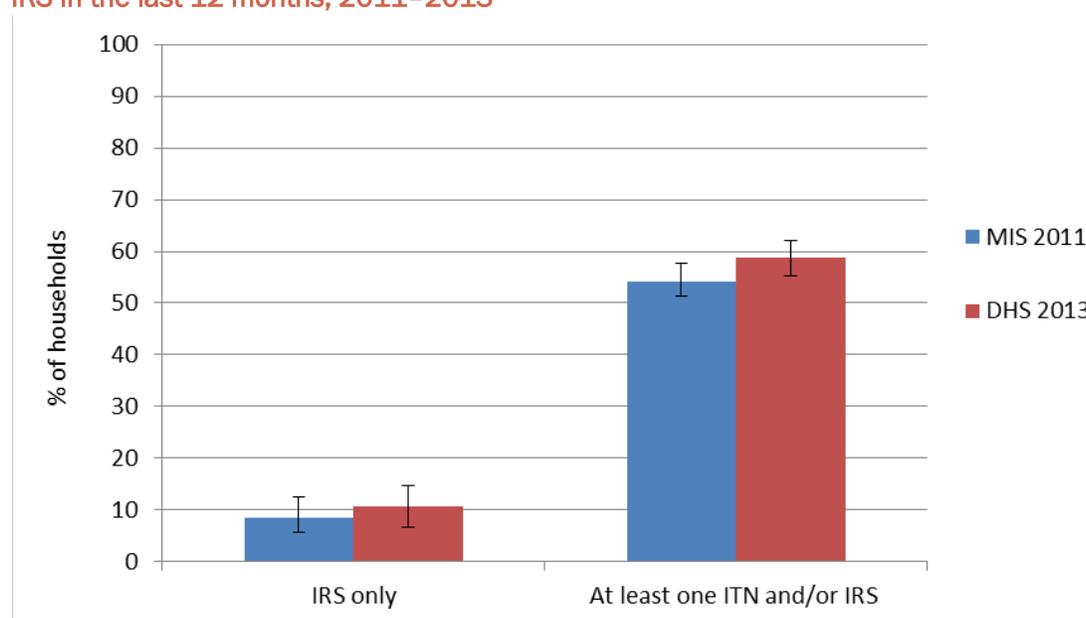
Year	Number of dwellings targeted	Number of dwellings sprayed	Population Protected	Locations Reached
2004–2008	n/a	n/a	n/a	Camps for internally displaced people in Montserrado and Bong Counties
2009	n/a	20,393	163,149	Margibi and Grand Bassa Counties
2010	n/a	48,375	420,537	Margibi, Grand Bassa and Montserrado Counties and Yekepa town
2011	n/a	110,427	834,671	Margibi, Grand Bassa, Montserrado and Bong Counties and Yekepa town
2012	99,236	96,901	869,707	Grand Bassa, Margibi, Montserrado, Bong, and Nimba Counties (14 districts total)
2013	44,328	42,708	367,930	Bong County

**Source:** National Malaria Control Program, PMI/AIRS Project Data

## IRS Coverage

National IRS coverage is defined in the 2011 MIS and 2013 DHS surveys as the percentage of households that were sprayed with insecticides in the 12 months before the survey was measured. Overall, national IRS coverage remained stable from 2011 to 2013, from 9% (95% CI: 6–13%) to 11% (95% CI: 8–15%). Coverage of households with at least one ITN and/or IRS in the last 12 months increased slightly from 54% (95% CI: 50–58%) in 2011 to 59% (95% CI: 55–62%) in 2013 (Figure 10).

**Figure 10: Percentage of households that received IRS and owned at least one ITN and/or received IRS in the last 12 months, 2011–2013**



Note: No data on IRS coverage is available from the 2007 DHS or the 2009 MIS.

# Intermittent Preventive Treatment in Pregnancy

## Background

Malaria prevention and control during pregnancy has a three-pronged approach, including IPTp, ITN use, and diagnosis and treatment of clinical illness. ITN use by pregnant women was previously discussed (ITN section, page 21). Data on case management of clinical illness in pregnant women are not collected in national household-based surveys and therefore are not included in this evaluation.

Malaria in pregnancy significantly raises the risk of severe illness in the pregnant woman and baby, including severe anemia, miscarriage, intra-uterine growth retardation, pre-term birth, and low birth weight [47, 48]. In high transmission settings, malaria is expected to be a significant indirect contributor to maternal death [49]. Malaria in pregnancy is thought to affect neonatal mortality risk via low birth weight and anemia in the newborn [50]. Use of ITNs and IPTp during pregnancy has been found to be associated with an 18% decreased risk of neonatal mortality and a 21% protective efficacy against low birth weight [51]. A randomized control trial in Mozambique found the use of IPTp to be associated with a 61% reduction in neonatal mortality [52]. Use of IPTp is likely to have a negligible impact on postneonatal mortality and ACCM, or on parasitemia or severe anemia prevalence in children 6-59 months of age.

## IPTp Policy and Implementation

IPTp was officially adopted in Liberia in 2003. Implementation began in 2005 as part of routine ANC services provided to pregnant women [28]. Implementation was prompted by the adoption of the First National Malaria Control Strategy (2000–2005). IPTp (2 or more doses of SP) was rolled out in the country through the training of health care providers on administration of IPTp, recording of IPTp data, and supervision and monitoring of IPTp services.

Table 10 shows the number of pregnant women who attended at least one or two ANC visits and the number that received one or two doses of SP during the ANC visit from 2008 to 2013. In general, coverage of SP has increased during this time, with less pregnant women receiving two doses, compared to one dose of SP. These data however, should be interpreted with caution due to the previously explained limitations with the HMIS data (refer to Limitations of the Evaluation section, page 5).

**Table 10: IPTp Implementation in Liberia: Number of Pregnant Women Attending at least one and two ANC visits and that Received 1 and 2 doses of SP, 2008-2013**

Year	# pregnant women that attended one ANC consultation	# pregnant women that received at least one dose of SP	# pregnant women that attended two ANC consultations	# pregnant women that received 2 doses of SP
2008	117,139	43,548	58,432	27,198
2009	205,438	83,677	89,378	48,923
2010	211,220	89,275	96,762	54,099
2011	222,764	98,695	104,770	66,167
2012	176,880	113,947	135,480	81,429
2013	157,241	108,371	120,755	89,431

Source: Liberia HMIS

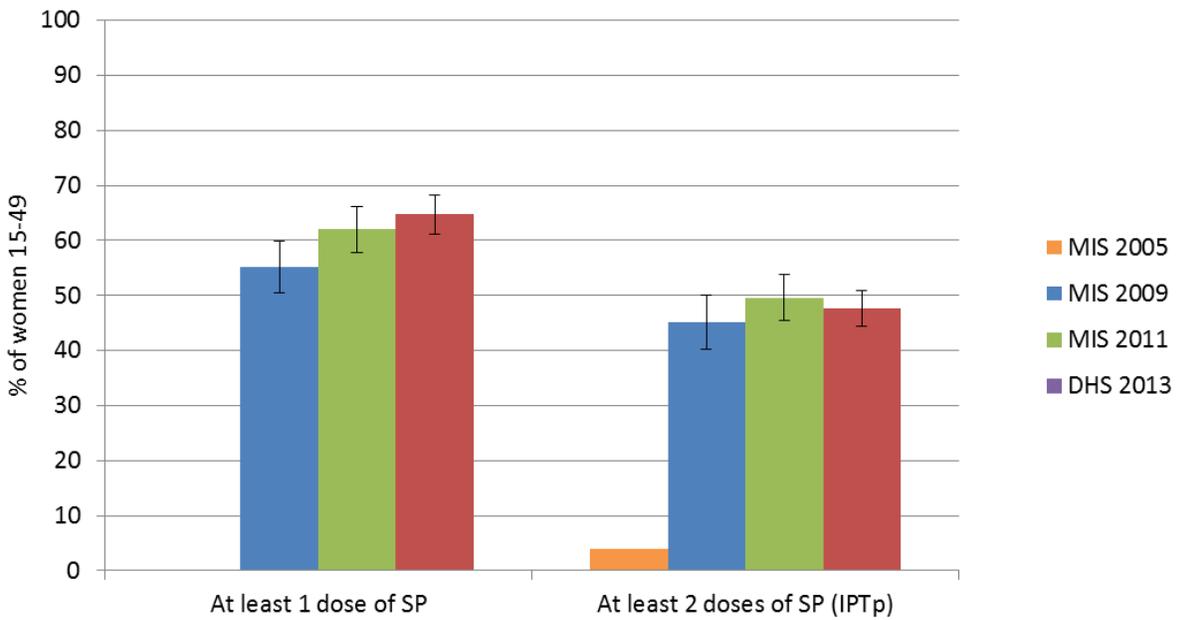
### Trends in IPTp coverage

The IPTp coverage indicator refers to women who received at least two doses of SP for malaria prevention, of which, at least one dose was received at an ANC clinic<sup>14</sup>. The indicator is restricted to the most recent pregnancy that resulted in a live birth, 0-2 years prior to the survey.

The percentage of women who received one dose of SP during an ANC visit gradually increased from 55% (95% CI: 50–60%) in 2009 to 65% (95% CI: 61–68%) by 2013. No earlier data on coverage of one dose of SP from the beginning of the evaluation period was available for analysis. Coverage of IPTp (2 or more doses of SP) increased significantly from 4% in 2005 to 48% (95% CI: 44–51%) in 2013 (Figure 11).

<sup>14</sup> IPTp coverage in the surveys (2007 DHS, 2009 MIS, 2011 MIS, and 2013 DHS) was measured as receipt of at least two doses of SP for malaria prevention as defined by the WHO-recommended policy at the time. The current national policy in Liberia recommends two or more doses of SP, to be received after the first trimester.

Figure 11: Percentage of women (15-49 years) with a live birth 0-2 years prior to survey who received at least one dose of SP and IPTp, 2005-2013



Note: No data on coverage of at least one dose of SP is available from the 2005 MIS.

## Equity in IPTp

Differences in IPTp coverage by residence, wealth, and mother's education across the 2009, 2011, and 2013 surveys are presented in Table 11. No significant differences were observed by place of residence, wealth quintile (comparing the least poor to the poorest), and education level across the survey years.

**Table 11: Proportion of women (15–49 years) with live birth 0–2 years prior to survey who received IPTp by socio-demographic factors, 2009–2013**

Background Characteristics	2009 MIS		2011 MIS		2013 DHS		Percentage point change 2009 to 2013
	% (95% CI)	WN	% (95% CI)	WN	% (95% CI)	WN	
<b>Residence</b>							
Urban	47.1 (38.5-55.8)	585	44.3 (39.1-49.6)	540	49.9 (45.4-54.5)	1351	2.8
Rural	43.9 (38.2-49.7)	988	53.8 (47.3-60.3)	689	45.2 (40.8-49.7)	1299	1.3
<b>Wealth</b>							
Lowest	38.6 (29.5-48.5)	390	54.3 (44.2-64.0)	304	42.1 (37.8-46.5)	636	3.5
Second	42.5 (36.8-48.3)	337	55.8 (48.6-62.8)	282	47.7 (41.7-53.8)	567	5.2
Middle	49.7 (41.3-58.1)	330	49.6 (42.2-57.0)	234	52.8 (46.7-58.8)	551	3.1
Fourth	48.2 (38.1-58.5)	303	40.2 (32.1-48.8)	227	46.5 (39.6-53.6)	509	-1.7
Highest	49.4 (37.9-60.9)	212	44.2 (34.2-54.8)	183	50.8 (41.7-59.8)	386	1.4
<b>Mother's Education</b>							
None	45.7 (39.1-52.3)	738	45.1 (38.4-51.9)	498	45.6 (41.1-50.2)	1000	-0.1
Primary	42.1 (37.0-47.4)	513	54.4 (48.9-59.8)	399	49.6 (45.1-54.1)	858	7.5
Secondary and higher	48.3 (39.0-57.8)	322	50.8 (44.1-57.4)	333	48.0 (42.9-53.2)	792	-0.3
<b>Total</b>	45.1 (40.2-50.0)	1573	49.6 (45.4-53.9)	1230	47.6 (44.4-50.8)	2650	2.5

## Summary of IPTp

Coverage of IPTp rose significantly from 4% in 2005 to just under 50% by the end of the evaluation period in 2013. Coverage remained stable during the latter part of the evaluation period from 2009 to 2013, increasing slightly from 45% to 48%, while coverage of at least one dose of SP during an ANC visit rose significantly from 55% in 2009 to 65% in 2013. No significant differences in IPTp coverage were found by place of residence, wealth quintile, or education level across the survey years.

# Malaria Case Management

## Background

Malaria case management, including the identification, diagnosis, and rapid treatment of all malaria cases with appropriate and effective antimalarial drugs, is one of the key strategic areas for malaria control recommended by the World Health Organization [53]. Most malarial fevers occur at home, and prompt and effective treatment is critical to prevent severe morbidity and mortality related to malaria.

## Case Management Policy and Implementation

From the late 1960s, Chloroquine was used as the first-line treatment of uncomplicated malaria in Liberia. Resistance to Chloroquine however was first noted in 1988 [27], with multiple efficacy studies in the 1990s confirming increased resistance to Chloroquine[54]. In 2002, resistance to SP, the second-line drug for treatment of uncomplicated malaria, was also documented, with resistance levels found to be as high as 69% [27, 55].

In 2003, consensus was reached between the Government of Liberia and partners on the need to change the first-line treatment for uncomplicated malaria to ACTs (specifically to AS-AQ). ACTs were first introduced by humanitarian international NGOs working in Southeastern Liberia, led by Médecins Sans Frontières (MSF). Thus, following WHO guidelines, Liberia changed its malaria treatment policy in 2003 and adopted AS-AQ as the first-line treatment for uncomplicated malaria [56]. However, it was not until 2005 that the Government of Liberia adopted the treatment regime for national use [16]. In 2009, the MOH/NMCP put in place a memorandum of understanding (MOU) with private health facilities to help eliminate the use of chloroquine and other monotherapies and increase access to ACTs. Private facilities benefitted from trainings on case management and received ACTs at no cost, as long as they treated patients free of charge and submitted monthly treatment reports to the NMCP.

From 2008 to 2011, an integrated community case management (iCCM) pilot project began in Liberia in Nimba and Sinoe Counties. The project trained just under 1,400 general community health volunteers (gCHVs), of which 225 gCHVs were trained in malaria case management in an effort to increase access to treatment at the community level [57, 58]. Training of gCHVs continued after the pilot; and by 2013 a total of 3,737 gCHVs were trained, 65% of whom had been trained in malaria case management [59]. The total number of gCHVs providing malaria diagnosis and treatment across the 15 counties however is unknown; reports suggest that treatment coverage has been low due to issues with lack of stock among gCHVs [58, 59]. In 2011, the National Therapeutic Guidelines for Liberia and Essential Medicines List, which covers malaria, were developed. A summary of key milestones in malaria case management are presented in Table 12.

**Table 12: Malaria Case Management Milestones in Liberia**

Year	Developments in Malaria Case Management in Liberia
Late 1960s	<ul style="list-style-type: none"> <li>• Chloroquine adopted as the first-line treatment for uncomplicated malaria.</li> </ul>
1988	<ul style="list-style-type: none"> <li>• First Resistance to Chloroquine, the 1st line drug for the treatment of uncomplicated malaria, noted.</li> </ul>
1993-1995	<ul style="list-style-type: none"> <li>• Efficacy studies confirmed increasing resistance to chloroquine.</li> </ul>
1999	<ul style="list-style-type: none"> <li>• MSF study in Maryland County confirmed high resistance to chloroquine.</li> </ul>
2002	<ul style="list-style-type: none"> <li>• Efficacy study demonstrated resistance to the second-line drug for treatment SP.</li> </ul>
2003	<ul style="list-style-type: none"> <li>• Government of Liberia and partners reached consensus on the need for a policy change for antimalarial treatment and Liberia adopted AS/AQ as the first-line treatment for uncomplicated malaria and oral quinine as the second-line treatment.</li> </ul>
2005	<ul style="list-style-type: none"> <li>• ACTs (AS/AQ) rolled-out nationally.</li> </ul>
2009	<ul style="list-style-type: none"> <li>• MOH/NMCP put in place an MOU with private health facilities to help improve coverage of treatment with ACTs.</li> </ul>
2010	<ul style="list-style-type: none"> <li>• Fixed dose ACTs (AS/AQ) introduced in the country; previously the drugs were procured and administered in a non-fixed formulation (i.e. blister packs).</li> </ul>
2011	<ul style="list-style-type: none"> <li>• National Therapeutic Guidelines for Liberia and the Essential Medicines List developed.</li> </ul>

## Diagnosics

Before 2003, malaria diagnosis in Liberia was largely based on clinical signs and symptoms since most health facilities in Liberia were not equipped with microscopes or trained medical laboratory technicians. However, in 2005, the new malaria treatment policy mandated that patients of all ages undergo diagnostic testing for malaria [60]. The Government of Liberia officially adopted the use of RDTs in 2003 and rolled them out to health facilities in 2005. To build local diagnostics capacity, training courses in malaria microscopy were held in 2009 and 2010 for laboratory technicians. These efforts have led to the increase in testing of suspected cases of malaria. HMIS health facility data report that the percent of suspected malaria cases tested rose from 73% in 2009 to 89% in 2013.

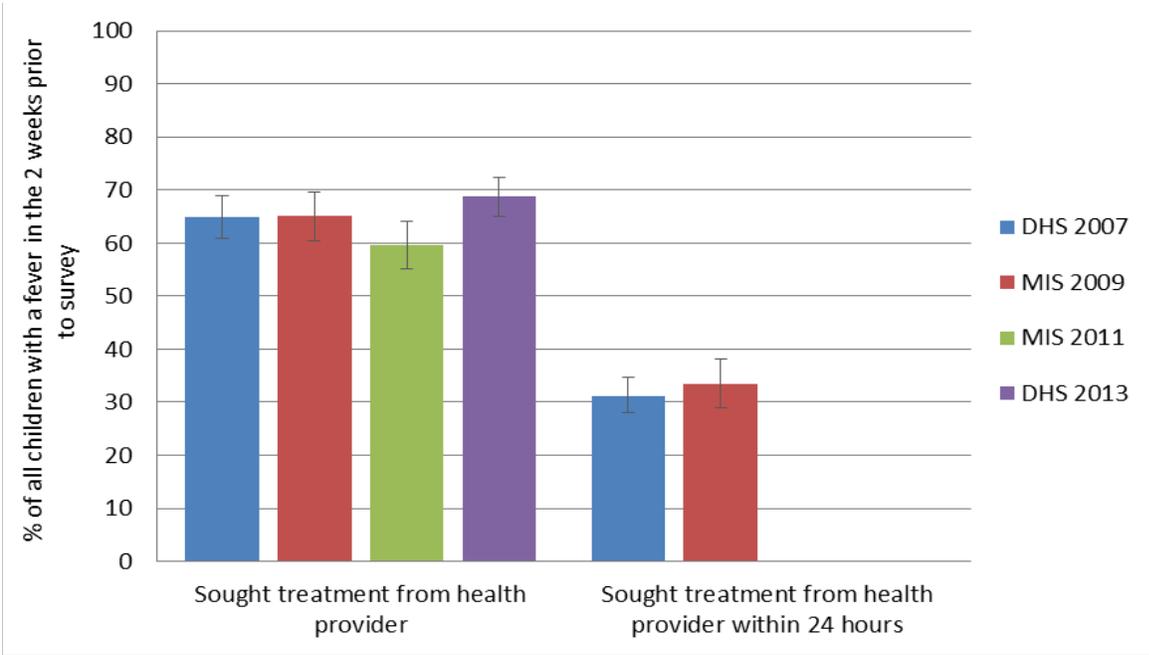
## Malaria Case Management in Children

Monitoring malaria case management is challenging. Correct and timely care of children with malaria depends on many factors including care-seeking behavior, access to health facilities, facility reporting of visits and diagnoses, diagnostic capacity, and availability of appropriate medicines. Measuring trends in malaria case management is further complicated by the policy changes that have occurred in the past decade, affecting both first-line medications and diagnostic procedures. As a result, the original RBM indicator measuring the proportion of children with recent fever who receive antimalarial treatment has been supplemented in this report with new RBM indicators: an estimate of the percentage of children with fever for whom treatment was sought from a health care provider; the percentage of treated children receiving recommended, first-line treatments; the percentage of treated children receiving recommended, first-line treatment among those that received any antimalarial; and the percentage of children with fever that had blood taken from a finger or heel (percent that received a diagnostic test).

The 2007 DHS, 2009 MIS, 2011 MIS, and the 2013 DHS surveys asked mothers to report history of fever in children under five years of age during the two weeks prior to the survey. Of children who experienced fever, a series of further questions are asked about care-seeking, including the source of advice or treatment, treatment received, and type of antimalarial used, if any. In the 2007 DHS and 2009 MIS, timing of care-seeking was also ascertained.

The percentage of children under five years of age with fever in the past two weeks for whom treatment was sought from a health provider did not vary significantly between 2007 and 2013, remaining stable from around 60% to just under 70% (Figure 12). Timely care-seeking within the first 24 hours of fever was only measured in the 2007 DHS and 2009 MIS, and remained stable at 31% and 33%, respectively across the two surveys.

**Figure 12: Percentage of children under five years of age with fever in the two weeks preceding the survey for whom treatment was sought from a health provider and for whom treatment was sought from a health provider within 24 hours of fever onset, 2007–2013**



**Equity in Care-seeking**

Differences in care-seeking for children under five years of age with fever in the two weeks preceding the survey by sex, place of residence, wealth quintile, and mother’s education level are presented in Table 13. Across all survey years no significant differences were observed in care-seeking by the sex of the child. However, care-seeking for fever was significantly lower in rural areas compared to urban areas across all survey years. Similar disparities were found by wealth quintile, with care-seeking lower for children from the poorest households compared to the least poor households in all survey years. Disparities were also observed by mother’s education level, with a general trend of greater care-seeking among children whose mother had a higher level of education. Overall, disparities

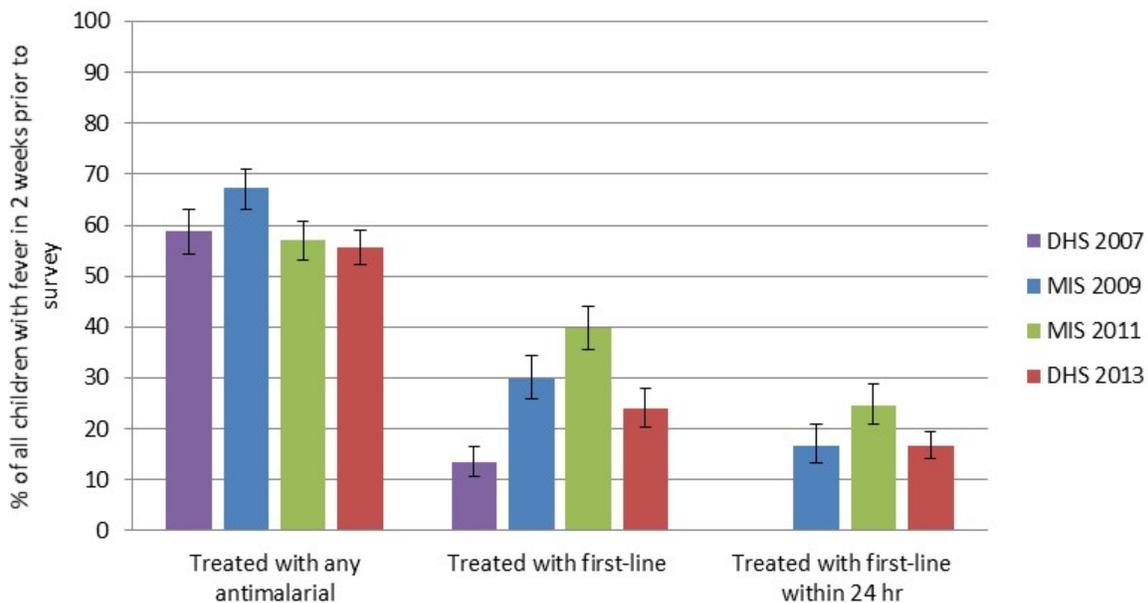
by place of residence, wealth quintile, and mother's education level remained unchanged over the evaluation period.

Table 13: Percentage of children under five years of age with fever in the two weeks preceding the survey for whom care was sought from a health provider, by socio-demographic factors, 2007–2013

Background Characteristics	2007 DHS		2009 MIS		2011 MIS		2013 DHS		Percentage point change 2007 to 2013
	% (95% CI)	WN							
<b>Sex</b>									
Male	67.1 (62.2-71.6)	814	66.3 (60.8-71.5)	834	58.2 (52.2-63.9)	744	69.9 (65.2-74.2)	938	2.8
Female	62.8 (57.4-67.9)	763	64.0 (58.1-69.5)	777	61.3 (56.3-66.0)	672	67.5 (62.9-71.8)	790	4.7
<b>Residence</b>									
Urban	77.0 (71.4-81.9)	450	74.2 (68.4-79.4)	659	68.2 (63.8-72.3)	583	76.8 (70.4-82.2)	793	-0.2
Rural	60.2 (54.8-65.3)	1,127	59.0 (51.8-65.7)	951	53.7 (46.7-60.5)	833	62.0 (57.8-66.0)	935	1.8
<b>Wealth</b>									
Lowest	46.3 (37.0-55.9)	309	57.0 (46.8-66.8)	365	47.3 (38.1-56.7)	355	58.0 (53.1-62.8)	460	11.7
Second	58.8 (50.7-66.5)	393	57.7 (48.1-66.7)	375	57.2 (49.5-64.6)	366	64.4 (57.5-70.8)	397	5.6
Middle	72.4 (65.2-78.6)	336	70.8 (62.6-77.9)	316	61.2 (52.0-69.6)	281	68.6 (61.5-74.9)	345	-3.8
Fourth	74.5 (68.6-79.6)	339	71.7 (62.0-79.8)	314	68.7 (62.4-74.3)	251	82.8 (77.4-87.1)	306	8.3
Highest	77.5 (68.9-84.2)	200	73.4 (64.9-80.5)	240	75.6 (66.0-83.2)	162	80.1 (65.7-89.4)	220	2.6
<b>Mother's Education</b>									
None	57.1 (51.4-62.7)	719	62.1 (55.5-68.2)	780	53.7 (47.4-59.9)	652	64.2 (59.0-69.2)	670	7.1
Primary	68.9 (62.5-74.6)	574	64.0 (56.6-70.8)	502	57.8 (52.2-63.2)	446	68.4 (63.4-72.9)	540	-0.5
Secondary or higher	77.5 (71.0-82.9)	282	74.5 (67.4-80.5)	328	74.6 (67.9-80.3)	317	75.1 (67.8-81.2)	518	-2.4
<b>Total</b>	65.0 (60.8-69.0)	1,577	65.2 (60.4-69.7)	1,610	59.7 (55.2-64.0)	1,416	68.8 (64.9-72.4)	1,728	3.8

Figure 13 shows the percentage of children under five years of age with fever in the two weeks preceding the interview who were treated with any antimalarial drug, with first-line antimalarial drugs, and with first-line antimalarial drugs within 24 hours of fever onset from 2007 to 2013. The percentage of children under five years of age with fever in the past two weeks that received any antimalarial drug increased from 59% (95% CI: 54–63%) in 2007 to 67% (95% CI: 63–71%) in 2009, but then declined to 56% (95% CI: 52–59%) in 2013. For the percentage of children under five years of age with fever in the past two weeks that were treated with first-line antimalarial drugs, there was a significant increase from 13% (95% CI: 11–17%) in 2007 to 40% (95% CI: 36–44%) in 2011, and then a significant decline to 24% (95% CI: 20–28%) in 2013. It is important to note that at the time of the 2013 DHS in Liberia, the first-line treatment was locally referred to as amodiaquine, making it difficult to distinguish use of the single drug and the ACT. Furthermore, fixed dose ACTs were introduced in Liberia in 2010 and amodiaquine as a monotherapy was no longer procured. Thus, it is likely that many of the children who were reported to have taken amodiaquine in the 2013 DHS actually received an ACT (Table 14), biasing the estimate of those that received first-line treatment downwards. Children with fever that were treated with first-line antimalarial drugs within 24 hours showed an increase from 17% (95% CI: 13–21%) in 2009 to 25% (95% CI: 21–29%) in 2011; and then declined to 17% (95% CI: 14–20%) in 2013. Similarly, the decline observed in 2013 may also be biased due to the recall bias in the 2013 DHS.

**Figure 13: Percentage of children under five years of age with fever in the two weeks preceding the survey who were treated with any antimalarial drug, with first-line antimalarial drugs, and with first-line antimalarial drugs within 24 hours of fever onset, 2007–2013**



Note: At the time of the 2013 DHS in Liberia, the first-line treatment was locally referred to as amodiaquine, making it difficult to distinguish use of the single drug and the ACT. Furthermore, with the introduction of fixed dose ACTs in 2010 and amodiaquine no longer procured as a monotherapy, it is likely that many of the children who were reported to have taken amodiaquine in the 2013 DHS actually received an ACT, biasing the estimate of those that received first-line treatment downwards.

Table 14 provides a breakdown of the specific antimalarial drugs taken by children under five years of age with fever among those that took any antimalarial drug. In 2007, the most frequently used antimalarial drugs were chloroquine (43%), followed by ACTs (15%) and amodiaquine (8%). In 2009, the most frequently used antimalarial drugs were ACTs (45%), followed by chloroquine (42%). There was a significant shift toward a greater proportion of ACTs being taken by children under five years of age in 2011 (70%), and less of chloroquine, with chloroquine accounting for 12% and amodiaquine and quinine accounting for 10%. In 2013, the percentage of children taking ACTs declined to 43%. However, as stated previously, it is possible that the percent of children that received an ACT was higher than reported. As in 2011, a small percentage of children were reported to have received chloroquine (10%), followed by quinine (7%) and SP (6%) among children that received any antimalarial in 2013.

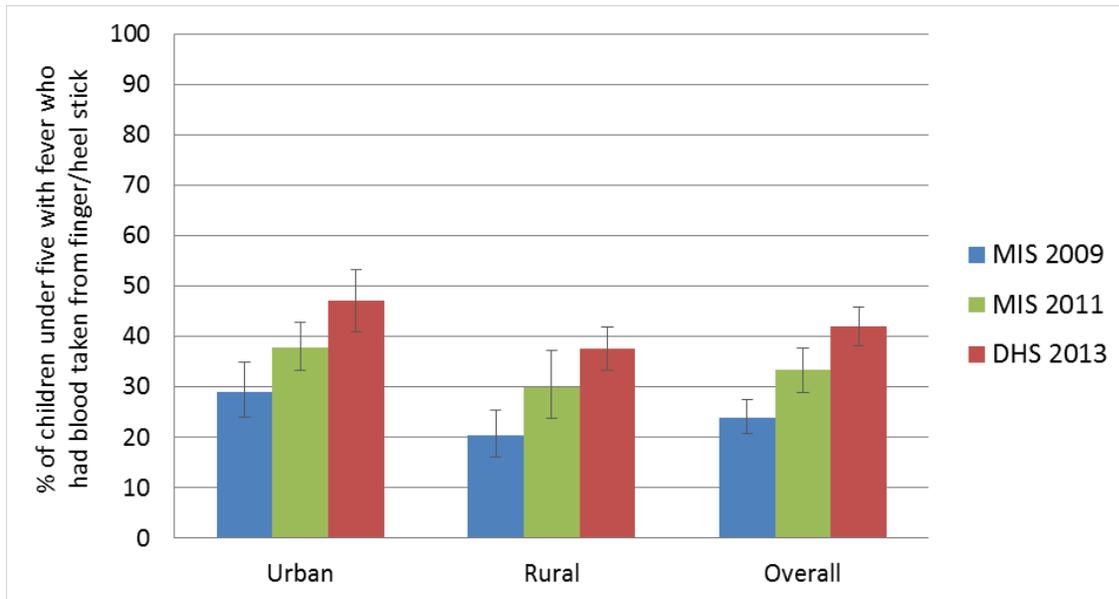
**Table 14: Among children under five with fever in two weeks prior to survey who received any antimalarial drug, proportion receiving each antimalarial drug 2007–2013**

<b>Antimalarial Drug</b>	<b>2007 DHS</b>	<b>2009 MIS</b>	<b>2011 MIS</b>	<b>2013 DHS</b>
ACT (AS + AQ)	15.1	44.6	69.6	42.9
Amodiaquine	7.8	0.0	9.9	42.2
Chloroquine	43.1	41.8	12.3	10.3
SP/Fansidar	3.2	0.5	0.2	5.5
Quinine	3.5	12.1	9.5	6.5
Other antimalarial drug	1.4	2.4	1.6	0.4
Total weighted number for any antimalarial drug	928	1081	808	1728

Measuring the extent to which children with fever obtained a parasitological diagnosis is important in making sure that appropriate treatment is based on parasitological confirmation as opposed to presumptive treatment. In household surveys, mothers or caregivers in the household are asked whether any of the children that had a fever in the past two weeks received a finger or heel stick. A finger or heel stick is used as a proxy for a malaria test. The mother is not specifically asked whether the finger or heel stick was conducted for malaria testing because some women may not know.

Figure 14 shows the percentage of children under five years of age with fever in the two weeks preceding the interview who had blood taken from a finger or heel at the national level and in urban and rural areas. Overall, diagnostic testing rose significantly from 24% (95% CI: 21–28%) in 2009 to 42% (95% CI: 38–46%) in 2013. Significant increases were observed in both urban and rural areas during the same time period, with coverage increasing from 29% (95% CI: 24–35%) to 47% (95% CI: 41–53%) in urban areas and from 21% (95% CI: 16–26%) to 38% (95% CI: 33–42%) in rural areas.

Figure 14: Percentage of children under five years of age with fever in the two weeks preceding the survey that had blood taken from a finger or heel by place of residence and nationally, from 2009–2013



Note: No data was available from the 2007 DHS.

### Malaria Case Management Summary

Overall, care-seeking for children under five years of age with fever in the previous two weeks remained stable during the evaluation period (ranging between 60–70%). Across the evaluation period, disparities were observed and remained unchanged in care-seeking by place of residence, wealth, and mother’s education level, with higher care-seeking observed for children from urban areas, the least poor households, and whose mother had a higher education level. Diagnostic testing for malaria also increased during the evaluation period from 24% in 2009 to 42% in 2013, with similar increases seen in both urban and rural areas. Treatment of children under five years of age with any antimalarial drug remained relatively stable during the evaluation period, from 59% in 2007 to 56% in 2013; however, there was a slight increase observed in 2009 to 67%. Treatment with first-line antimalarial drugs improved significantly from 13% in 2007 to 40% in 2011. The decline observed in treatment with a first-line antimalarial drugs in 2013 is hard to interpret, and may have been due to the challenge of measuring receipt of an ACT in the survey.

# MALARIA MORBIDITY

# Malaria Parasitemia

## Background

Reductions in malaria parasitemia prevalence serve as a proxy for reductions in malaria-specific morbidity at the population level. MIS and DHS surveys are the main data collection tools that have been used to collect malaria parasitemia data. In Liberia, both the 2009 and 2011 MIS surveys collected malaria parasitemia data.

Malaria transmission dynamics are quite sensitive to seasonal and yearly climate variability [61] and are heterogeneous over small areas [61, 62], which could mask successes or lapses in malaria control efforts [63-65]. Therefore, national prevalence data conducted at time of household surveys may be a crude method for monitoring progress in malaria control, although it is arguably the most direct measure of success among the outcomes we evaluated.

## Trends in Malaria Parasitemia

The 2009 and 2011 MIS tested children 6-59 months of age for the presence of *P. falciparum* parasites using RDTs<sup>15</sup> and thick blood smears for microscopic analysis [26, 66]. The 2009 survey took place from mid-December 2008 to March 2009, during the dry season; while the 2011 survey took place from September 2011 to December 2011, which overlapped with the rainy season and peak malaria-transmission season. It is important to note that in the 2011 survey, an external quality control analysis of a subsample of the microscopy slides revealed that a large proportion of the slides (22%) were unreadable. The unreadable slides were excluded from the malaria prevalence calculations. Because of this, both the RDT and microscopy results are presented in this section since the 2011 microscopy results should be interpreted with some caution.

Figure 15 presents the trends in malaria parasitemia prevalence by age group using RDTs. Across all age groups, malaria parasitemia prevalence by RDT increased from 2009 to 2011. Among children 6-59 months of age, prevalence increased from 37% (95% CI: 32–41%) to 45% (95% CI: 41–48%). In children 6-23 months of age, parasitemia prevalence by RDT rose from 25% (95% CI: 21–30%) to 33% (95% CI: 29–37%) and in children 24-59 months of age, prevalence increased from 43% (95% CI: 38–47%) to 51% (95% CI: 47–55%). The 2005 MIS reports that parasitemia prevalence by RDT for children 6-59 months of age was 66%, demonstrating that there was a 21% decline between 2005 and 2011. The 2005 MIS was conducted during the rainy season (July – August 2005), and therefore likely more comparable to the 2011 MIS.

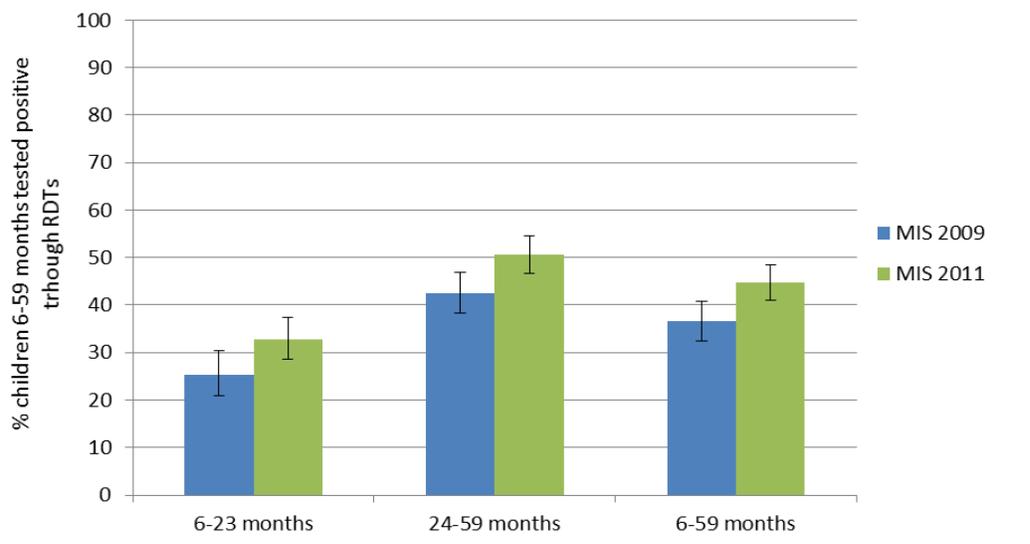
Figure 16 shows the malaria parasitemia prevalence in children 6-59 months of age, 6-23 months, and 24-59 months, for 2009 and 2011 using microscopy. There was no significant change in malaria parasitemia prevalence by microscopy in any age group between the two survey years.

---

<sup>15</sup> In the 2009 MIS, the Paracheck® RDT was used and in the 2011 MIS, the First Response® RDT was used.

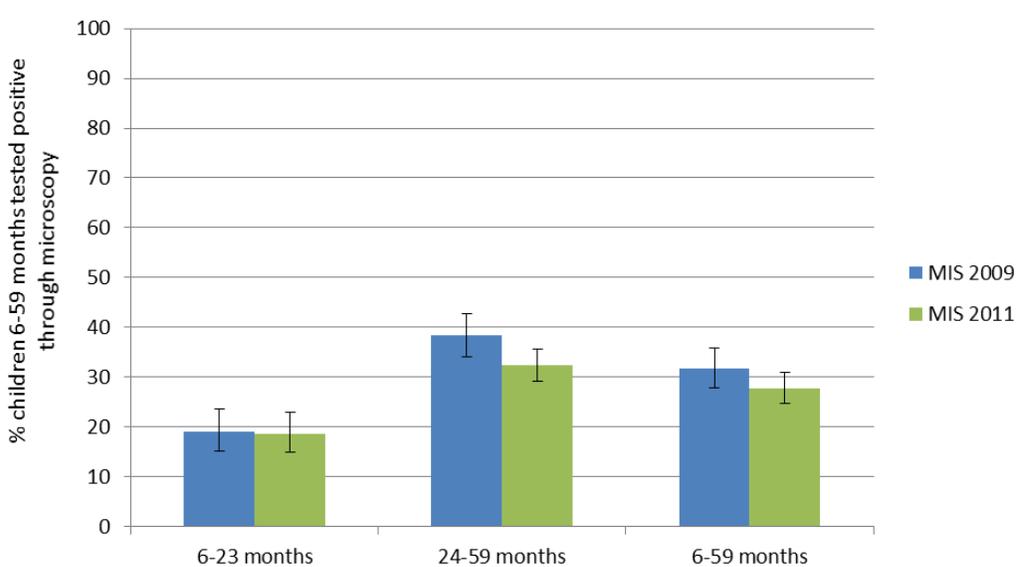
In 2009 and 2011, malaria parasitemia prevalence measured via RDT and microscopy was significantly lower in children 6-23 months of age compared to children 24-59 months of age.

**Figure 15: Trends in malaria parasitemia prevalence (RDT) by age group, 2009–2011**



Note: No data was collected on parasitemia prevalence in the 2007 DHS or 2013 DHS.

**Figure 16: Trends in malaria parasitemia prevalence (microscopy) by age group, 2009–2011**



Note: No data was collected on parasitemia prevalence in the 2007 DHS or 2013 DHS.

Table 15, which shows malaria parasitemia prevalence measured through RDT broken down by age groups, shows a similar trend with parasitemia prevalence increasing with age, and significantly higher in the oldest age group compared to the youngest age group. In other high-burden countries, malaria parasitemia prevalence is higher in older children

(24-59 months) living in malaria endemic areas since they build immunity over time and more likely to have an asymptomatic infection. Table 16 shows malaria parasitemia prevalence measured through microscopy further broken down by age groups. Across survey years, parasitemia prevalence via microscopy increased with age, and was significantly higher among the oldest age group (48–59 months) compared to the youngest age group (6–11 months).

Trends in parasitemia from 2009 to 2011 differed depending on the measurement type. For parasitemia prevalence measured via RDT, increases were observed across all age groups; while for microscopy, all age groups showed a slight decline in parasitemia prevalence from 2009 to 2011, with the exception of the 6–11 months group.

**Table 15: Malaria parasitemia (RDT) in children 6-59 months, by age group, 2009–2011**

Age in months	2009 MIS				2011 MIS				Percentage point change
	% of children with malaria parasitemia	95% CI	WN		% of children with malaria parasitemia	95% CI	WN		
6-11	16.1	10.9 23.0	501		25.7	19.6 32.9	252		9.6
12-23	30.0	25.4 35.1	966		35.5	30.6 40.7	674		5.5
24-35	37.9	32.6 43.5	906		45.4	40.4 50.4	591		7.5
36-47	44.5	39.1 50.1	900		50.9	45.0 56.8	658		6.4
48-59	44.8	39.7 49.9	977		54.9	49.4 60.2	640		10.1
<b>Total</b>	<b>36.5</b>	<b>32.4 40.8</b>	<b>4,250</b>		<b>44.7</b>	<b>41.1 48.4</b>	<b>2,815</b>		<b>8.2</b>

**Table 16: Malaria parasitemia (microscopy) in children 6-59 months, by age group, 2009–2011**

Age in months	2009 MIS				2011 MIS				Percentage point change
	% of children with malaria parasitemia	95% CI	WN		% of children with malaria parasitemia	95% CI	WN		
6-11	11.2	7.0 17.5	501		14.5	9.9 20.7	252		3.3
12-23	23.0	18.9 27.7	966		20.1	15.8 25.2	674		-2.9
24-35	34.0	28.7 39.7	906		27.7	23.8 32.0	591		-6.3
36-47	39.6	34.6 44.9	900		33.4	28.9 38.2	658		-6.2
48-59	41.3	35.8 47.0	977		35.4	30.6 40.6	640		-5.9
<b>Total</b>	<b>32.0</b>	<b>27.8 35.9</b>	<b>4,250</b>		<b>27.8</b>	<b>24.8 31.0</b>	<b>2,815</b>		<b>-4.2</b>

### Equity in Malaria Parasitemia

Malaria parasitemia prevalence (via RDT) in children age 6-59 months of age by socio-demographic characteristics is shown in Table 17. No significant differences were found in malaria parasitemia prevalence by the sex of the child in either 2009 or 2011. A large disparity was observed in parasitemia prevalence by place of residence in both survey years; with significantly higher prevalence among children from rural areas (42% and 55% in 2009 and 2011, respectively) compared to children from urban areas (27% and 30% in 2009 and 2011, respectively). Significant differences were also found in malaria

parasitemia prevalence by wealth and mother's education level in 2009 and 2011. Parasitemia prevalence was significantly lower among children from the least poor households in 2009 and 2011 (17% and 14%, respectively) compared to children from the poorest households (40% and 54%, respectively); and similarly, was significantly lower in children whose mother had a secondary or higher education level (22% and 29%, respectively) compared to those whose mother had no education or a primary level of education (38% and 50%, respectively). Overall, the differences observed by place of residence, wealth quintile, and mother's education level remained stable across both survey years. The same trends observed in parasitemia prevalence measured through RDT, were found in parasitemia measured through microscopy – significant differences were observed in both 2009 and 2011 in parasitemia prevalence by place of residence, wealth, and mother's education level (data presented in Annex A, Table A.3.1.16).

**Table 17: Malaria parasitemia (RDT) in children 6-59 months, by background characteristics, 2009–2011**

Background Characteristics	2009 MIS				2011 MIS				Percentage point change 2009 to 2011
	%	95% CI	WN	%	95% CI	WN			
<b>Sex</b>									
Male	37.1	32.5 41.9	2,152	46.5	42.1 50.8	1,494		9.4	
Female	36	31.3 41	2,104	42.8	38.8 47	1,426		6.8	
<b>Residence</b>									
Urban	26.7	22.8 31	1,597	29.5	23.2 36.7	1,149		2.8	
Rural	42.4	36.4 48.7	2,659	54.5	50.1 58.9	1,770		12.1	
<b>Wealth</b>									
Lowest	40.2	33.8 46.9	1,016	54	48.3 59.6	771		13.8	
Second	45.4	39.3 51.7	979	54.1	48.7 59.4	701		8.7	
Middle	40.9	34.4 47.8	884	50.4	43.9 56.9	595		9.5	
Fourth	29.9	22.8 38.1	803	33.4	24 44.4	470		3.5	
Highest	17.4	12.1 24.5	574	13.6	9.9 18.4	383		-3.8	
<b>Mother's Education</b>									
None	38.2	32.9 43.9	1,616	50	45.4 54.6	1,076		11.8	
Primary	36.2	31 41.7	930	47.6	41.8 53.4	677		11.4	
Secondary or higher	22	16.7 28.4	562	28.9	23.3 35.1	475		6.9	
Missing	41.5	35.9 47.4	1,147	44.5	38.8 50.3	692		3.0	
<b>Total</b>	36.5	32.4 40.8	4,255	44.7	41.1 48.4	2,920		8.2	

# Severe Anemia

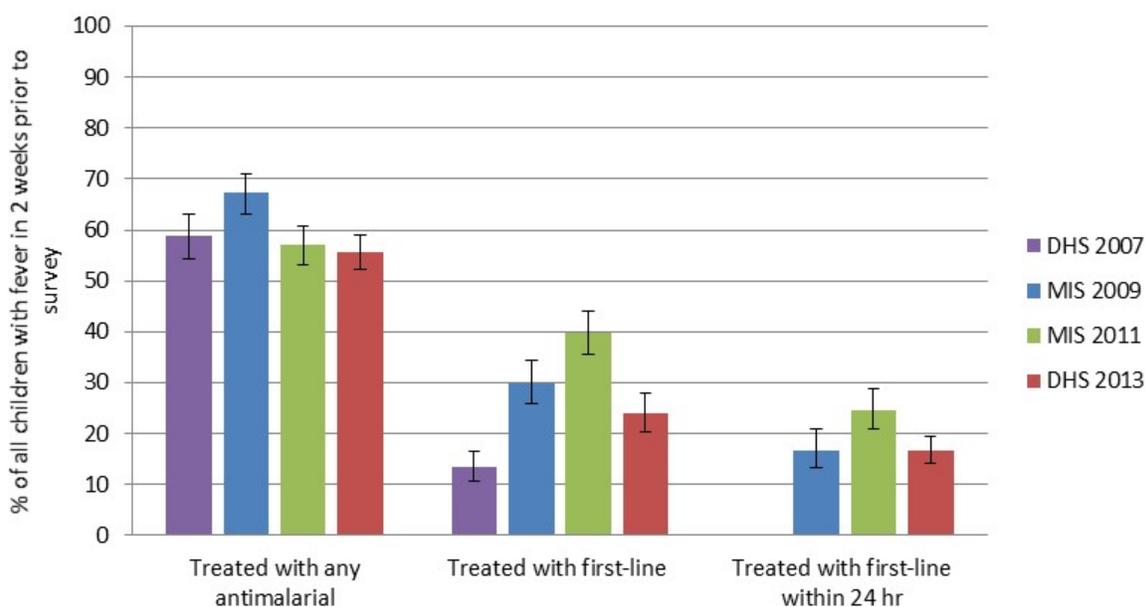
## Background

Severe anemia, defined as blood hemoglobin levels less than 8 grams per deciliter (g/dL) is associated with malaria-related mortality. As an indicator of malaria control, it exhibits less seasonality than malaria parasitemia [9, 11-13, 53]. Infection with malaria parasites may lead to anemia through the sequestration and lysis of red blood cells, and to suppressed production of new cells in the bone marrow (dyserythropoiesis) [67]. In addition to malaria parasites, iron deficiency, deficiencies in other nutrients, and diseases such as soil-transmitted helminths are all causes of anemia [67]. Declines in severe anemia have been found to be associated with malaria control interventions [68]. More population-level surveys have collected prevalence of severe anemia than parasitemia, and therefore, trends are more easily established using retrospective survey data. In sub-Saharan Africa, between 17% and 54% of malaria-attributable deaths are estimated to be due to severe anemia [68-71].

## Trends in Severe Anemia

National estimates of the prevalence of severe anemia in children aged 6-59 months of age are available from the 2009 and 2011 MIS. Figure 17 shows the trends in severe anemia prevalence in children 6-59 months of age, 6-23 months of age, and 24-59 months of age. The prevalence of severe anemia slightly increased in all age groups between 2009 and 2011. Among children 6-59 months of age, the prevalence of severe anemia increased significantly from 5% (95% CI: 4–6%) to 8% (95% CI: 6–9%). A similar trend was observed in children 6-23 months of age and children 24-59 months of age, with children 6-23 months of age showing an increase from 7% (95% CI: 5–9%) to 10% (95% CI: 8–12%), and children 24-59 months of age showing a significant increase from 4% (95% CI: 3–5%) to 7% (95% CI: 5–8%).

Figure 17: Trends in severe anemia (hemoglobin < 8g/dL) prevalence by age group, 2009–2011



Note: No data was collected on severe anemia prevalence in the 2007 DHS or 2013 DHS.

Table 19 shows severe anemia prevalence among children 6-59 months of age further broken down by age groups. Across all age groups, severe anemia increased from 2009 to 2011; however, none of the increases were found to be statistically significant. Overall, severe anemia was lower in the two oldest age groups (36-47 and 48-59 months) compared to children from the younger age groups (6-11, 12-23, and 24-35 months) in both survey years. The greatest increases in severe anemia from 2009 to 2011 were observed in children 6-11 months of age (5% to 9%), 24-35 months of age (6% to 10%), and 36-47 months of age (3% to 7%).

**Table 18: Severe anemia (hemoglobin < 8g/dL) prevalence by age group, 2009-2011**

Age in months	2009 MIS				2011 MIS				Percentage point change
	% of children with severe anemia	95% CI	WN		% of children with severe anemia	95% CI	WN		
6-11	4.8	2.9	8.0	500	9.0	5.2	15.1	265	4.2
12-23	7.6	5.5	10.5	968	10.0	7.8	12.8	706	2.4
24-35	6.1	4.2	8.6	910	10.1	7.4	13.7	616	4.0
36-47	2.8	1.4	5.4	901	6.6	4.6	9.3	683	3.8
48-59	2.4	1.4	4.2	979	3.4	2.1	5.6	672	1.0
<b>Total</b>	4.7	3.8	5.9	4260	7.7	6.4	9.1	2942	3.0

### Equity in Severe Anemia

The prevalence of severe anemia in children 6-59 months of age by socio-economic characteristics is presented in Table 19. No significant differences were observed in severe anemia prevalence by sex of the child, place of residence, wealth quintile, or mother's education level in either 2009 or 2011. Severe anemia was slightly higher among children from the poorest households compared to children from the least poor households in both survey years, however the differences were not significant.

Table 19: Severe anemia (hemoglobin < 8g/dL) prevalence in children 6-59 months of age, by background characteristics, 2009–2011

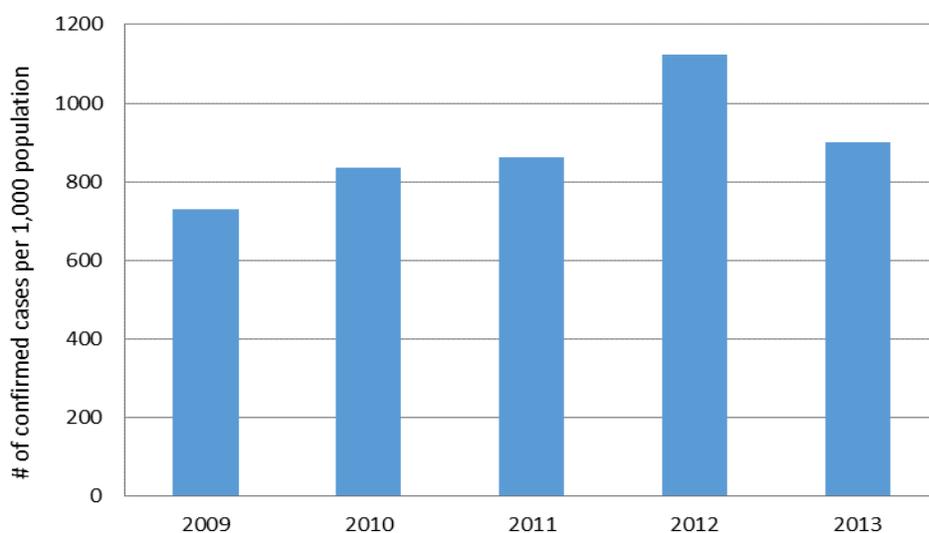
Background Characteristics	2009 MIS		2011 MIS		Percentage point change 2009 to 2011
	% (95% CI)	WN	% (95% CI)	WN	
<b>Sex</b>					
Male	4.8 (3.7-6.2)	2,154	8.1 (6.5-10.1)	1,502	3.3
Female	4.6 (3.6-6.0)	2,104	7.1 (5.6-9.1)	1,440	2.5
<b>Residence</b>					
Urban	5.0 (3.8-6.6)	1,599	7.0 (5.1-9.6)	1,160	2.0
Rural	4.6 (3.4-6.2)	2,660	8.1 (6.6-10.0)	1,782	3.5
<b>Wealth</b>					
Lowest	5.3 (3.9-7.1)	1,017	7.6 (5.7-10.1)	775	2.3
Second	5.5 (3.8-7.9)	979	8.2 (6.2-10.9)	703	2.7
Middle	3.8 (2.4-5.8)	884	8.7 (6.4-11.8)	604	4.9
Fourth	4.3 (2.7-6.7)	806	7.0 (4.3-11.2)	474	2.7
Highest	4.6 (2.9-7.2)	574	5.8 (3.6-9.3)	386	1.2
<b>Mother's Education</b>					
None	5.2 (3.8-7.0)	1,616	7.4 (5.8-9.3)	1,084	2.2
Primary	5.7 (4.0-8.2)	931	10.1 (7.5-13.4)	680	4.4
Secondary or higher	4.8 (3.0-7.6)	562	7.4 (4.6-11.5)	481	2.6
Missing	3.3 (2.2-5.1)	1,149	5.9 (3.7-9.3)	697	2.6
<b>Total</b>	4.7 (3.8-5.9)	4,260	7.7 (6.4-9.1)	2,815	3.0

## Facility-based Malaria Cases Data

Data from the HMIS were used to investigate trends in malaria cases between 2009 and 2013.<sup>16</sup> Although the Liberia HMIS has not been formally evaluated for accuracy, it represents the only source of national-level data on clinical malaria over time. However, when examining HMIS data it is important to be aware of a few challenges that may affect the quality of the data. These challenges include inaccurate and incomplete reporting, and changes over time in the number of facilities reporting data. In Liberia specifically, the HMIS was introduced in 2009 and was migrated to the DHIS2 platform in 2011. No data on the health facility reporting rate is available between 2009 and 2011; however, the health facilities reporting rate was generally high at 85% in 2012 and 89% in 2013.

Figure 18 and 19 present the number of confirmed malaria cases among children under five years of age and for people five years of age and above adjusted for population size from 2009 to 2013 (detailed results are presented in Table 20). The number of confirmed malaria cases (via RDTs and microscopy) among children under five years of age increased gradually from 2009 to 2011, and then spiked in 2012 to 1,122 cases per 1,000 population, before declining to an estimated 899 cases per 1,000 population in 2013. The number of confirmed malaria cases among people five years of age and above steadily increased from 2009 to 2012, from 216 to 313 cases per 1,000 population, and then declined to 240 cases per 1,000 population in 2013. The increase observed in cases between 2009 and 2012 is likely in part due to a greater percentage of health facilities reporting in 2012 compared to previous years, to the increasing number of health facilities providing malaria services during this time period, and to a greater percentage of suspected cases being tested in 2012 (Figure 20).

**Figure 18: Number of confirmed malaria cases among children under five per 1,000 population, 2009–2013**



<sup>16</sup> No previous data from the beginning of the evaluation period were available.

Figure 19: Number of confirmed malaria cases among individuals five years and above per 1,000 population, 2009–2013

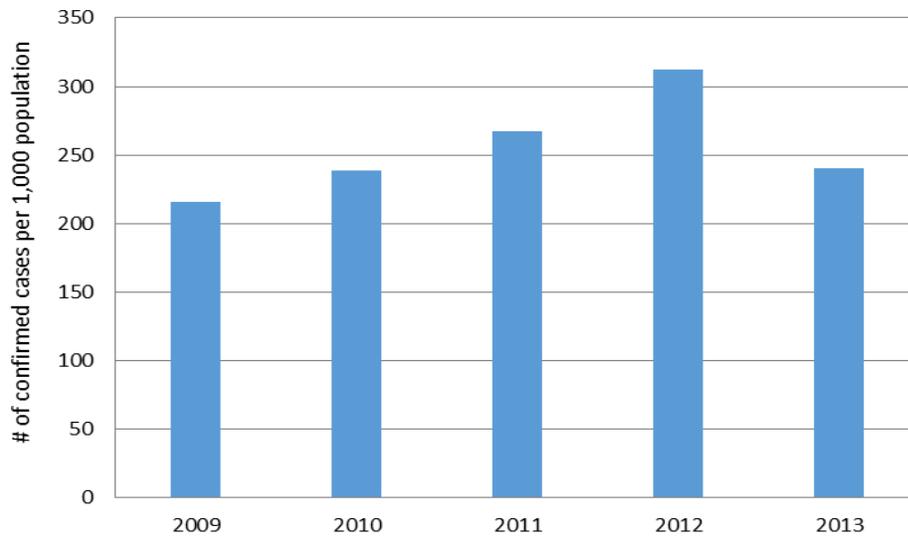


Figure 20: Percent of suspected cases tested among children under five and for those five years of age and above, 2009–2013

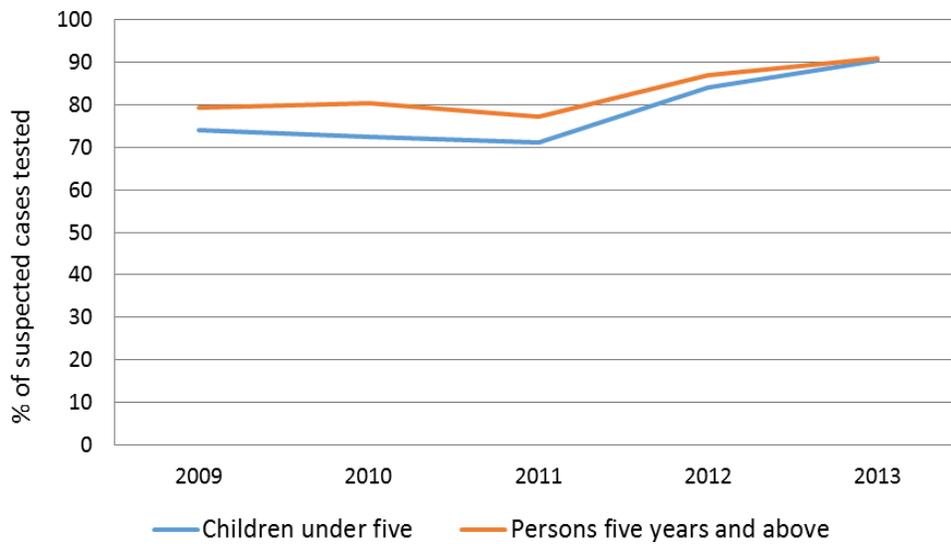


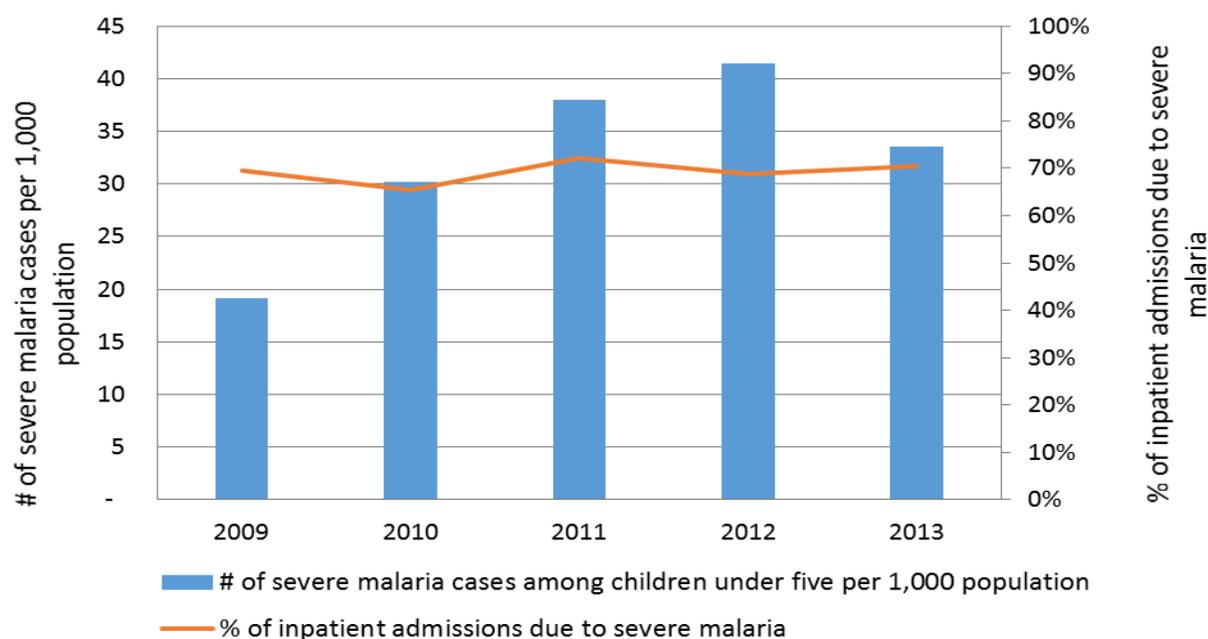
Table 20: Trends in the number of confirmed malaria cases among children under five and for those five years of age and above, adjusted for population size

Year	Population above 5 years of age			Population of under five years of age		
	Estimated population	# of confirmed malaria cases	# confirmed malaria cases per 1,000 population	Estimated population	# of confirmed malaria cases	# confirmed malaria cases per 1,000 population
2009	3,182,000	686,098	216	641,000	468,063	730
2010	3,300,000	788,603	239	655,000	546,572	834
2011	3,411,000	910,483	267	668,000	576,005	862
2012	3,512,000	1,097,633	313	678,000	760,740	1122
2013	3,609,000	866,777	240	686,000	616,987	899

Source: HMIS data. Population estimates are from the UN population database.

Figure 21 presents the number of severe malaria cases among children under five years of age alongside the percent of inpatient admissions that are due to severe malaria from 2009 to 2013. The number of severe malaria cases steadily increased from 2009 to 2012, from 19 to 41 cases per 1,000 population, and then declined in 2013 to 34 cases per 1,000 population, while the percent of inpatient admissions due to severe malaria remained stable over the same time period, ranging from 65-72%. It is possible that the rise observed from 2009 to 2012 is due to increases in the coverage of health facilities reporting data into the HMIS, given that the percent of inpatient admissions during this time remained stable.

Figure 21: Number of severe malaria cases among children under five per 1,000 population and percent of inpatient admissions due to severe malaria



## Summary of Malaria Morbidity

Overall across the evaluation period, malaria parasitemia prevalence measured through RDTs showed a decline from 66% in 2005 to 45% in 2011; however, it is important to note that prevalence measured via RDTs did increase significantly between the 2009 and 2011 surveys. Parasitemia measured via microscopy showed prevalence declining slightly between 2009 and 2011, however this trend should be interpreted with caution due to quality issues noted with a proportion of the microscopy slides during survey implementation. It is also important when examining these trends to take into account the difference in the timing of the 2009 and 2011 surveys, with the 2011 survey taking place during part of the rainy season and the 2009 survey taking place in the dry season. It is possible that the difference biased the extent of the increase observed via RDTs over the two survey periods. Furthermore, the 2005 MIS was conducted during the rainy season and thus likely more comparable to the 2011 MIS (for RDTs). There were striking differences in malaria parasitemia (measured through RDTs and microscopy) found across place of residence, wealth quintile, and mother's education level, with greater prevalence of parasitemia found among children from rural areas, the poorest households, and whose mother had a primary level of education or lower across both survey years.

Severe anemia prevalence increased from 5% to 8% between 2009 and 2011. The prevalence of severe anemia increased slightly across all age groups between the two survey years. No significant differences were found in severe anemia prevalence by sex, place of residence, wealth, or mother's education level. As with the parasitemia data, it is important to take into account the timing of the surveys when looking at trends in severe anemia, as the slight increases observed may be in part due to the different timing of the surveys.

Overall, the number of confirmed malaria cases among children under five years of age and among individuals five years of age and above increased between 2009 and 2012, and then showed a decline in 2013. A similar trend was observed in severe malaria cases among children under five years of age during this same time period. It is possible that increases in cases seen between 2009 and 2012 are in part due to increases in the coverage of health facilities reporting, the expansion of health facilities providing services during this time frame, and the increase in the percentage of suspected cases being tested (for confirmed malaria cases).

Overall, the limited data points available on parasitemia, severe anemia, and malaria cases, and the issue of seasonality and coverage of the HMIS data, make it challenging to accurately assess and draw conclusions on trends in malaria morbidity over the entire evaluation period. Despite the limitations, the evidence suggests a decline in parasitemia prevalence from 2005 to 2011, and a decline in malaria cases occurring toward the end of the evaluation period (between 2012 and 2013).

# MORTALITY

## Mortality

### Background

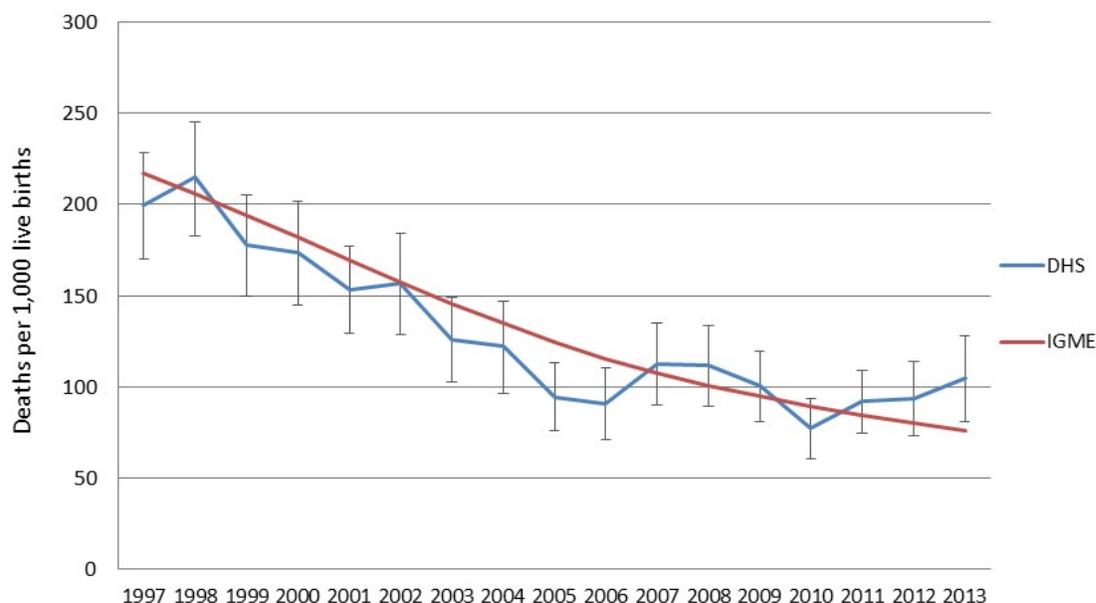
This section reviews recent trends in ACCM in Liberia, with a view to assessing the magnitude, timing, and age-pattern of change between the 2007 and 2013 surveys. All mortality figures represent direct estimates and are presented as either estimates of the period 0-4 years before each survey or as annual estimates. ACCM trends from the United Nations Inter-Agency Group for Mortality Estimation (IGME) are included in figures where relevant for comparative purposes.

Mortality estimates presented in this evaluation are derived from the 2007 and 2013 DHS datasets rather than mortality estimates available from IGME. The level and detail of stratification needed to inform the plausibility design of this evaluation was not possible using IGME estimates. IGME mortality estimates are presented and discussed when applicable.

### Trends in All-cause Mortality of Children Under Five Years of Age (ACCM)

Annual ACCM estimates from DHS and IGME during the time period 1997 to 2013 are presented in Figure 22. Although DHS reports typically present five-year estimates of mortality it is possible to generate annual mortality estimates for the ten-year period preceding the survey. These estimates typically have greater levels of uncertainty due to the smaller sample sizes but allow closer examination of the trends in ACCM both before and during the evaluation time period. As Figure 21 shows, there was an overall steady decline in ACCM from 1997 to 2006, from 200 (95% CI: 170–228) to 91 deaths (95% CI: 71–110) per 1,000 live births. Between 2006 and 2013, ACCM fluctuated with a slight increase to 112 (95% CI: 89–133) deaths per 1,000 live births in 2008, followed by a decline to 77 deaths (95% CI: 60–93) in 2010, and then a gradual increase to 104 (95% CI: 80–128) deaths per 1,000 live births in 2013. The fluctuations observed after 2006 were not statistically significant, however, it is important to highlight that there was not a steady decline observed during the period (2006–2013) when the coverage of malaria control interventions was expanded. The IGME estimates on the other hand, show a steady decline from 1997 through 2013; though the rate of decline is similar in the period prior to and during the evaluation period when coverage of malaria control interventions was expanded. Overall, the annual ACCM estimates and the IGME estimates correspond and suggest that the rate of decline prior to the expansion of malaria interventions did not differ with the rate of decline after the expansion of interventions.

Figure 22: Trends in annual ACCM (1997–2013), Liberia from 2007 and 2013 DHS and IGME Estimates



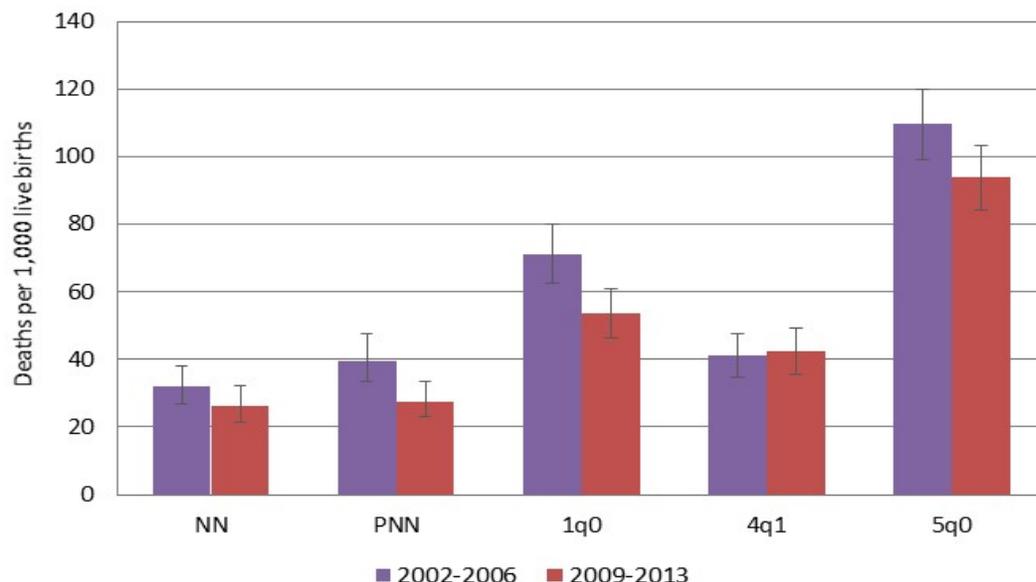
### Trends in Age-specific Childhood Mortality

Trends in age-specific childhood mortality from the 2007 and 2013 DHS, are presented in Figure 23. Overall, childhood mortality decreased in neonates, post-neonates, and infants, however the decline was only significant for infants. Childhood mortality (4q1) remained stable across both the 2007 and 2013 surveys, at 41 and 42 deaths per 1,000 live births, respectively. Overall, under-five mortality decreased from 109 to 94 per 1,000 live births, though the decrease was not significant (Table 21).

The mortality estimates and relative change (from 2007 to 2013) in these estimates by age categories are shown in Table 21. Four additional age categories are included: 6-23 months of age (where malaria-related mortality would be expected to be concentrated), 24-59 months of age, 1-59 months of age, and 6-59 months of age (for comparison). There was a decline across all age categories, except for child mortality (4q1) which remained stable between 2002–2006 and 2009–2013. Overall post-neonatal mortality and infant mortality experienced the greatest relative decline (30% and 25%, respectively) between the 2002–2006 and 2009–2013 time periods.

If a major proportion of ACCM was due to malaria, declines in malaria deaths over the period of expansion in malaria control interventions should be greatest in the children most susceptible to severe malaria outcomes; that is, greater among 6-23 month-old children compared to those aged 24-59 months of age. The relative decline however in both these age groups was similar and overall was small, at 10% and 6%, respectively.

Figure 23: Trends in age-specific childhood mortality, Liberia, five-year estimates from the 2007 and 2013 DHS



Notes: NN = neonatal mortality (first month), per 1,000 live births; PNN = post-neonatal mortality (age 1-11 months), per 1,000 live births;  $1q_0$  = infant mortality (first year), per 1,000 live births;  $4q_1$  = child mortality between 12 and 59 months of age, per 1,000 children surviving to 12 months of age;  $5q_0$  = under-five mortality, per 1,000 live births.

Table 21: Age-specific mortality (deaths per 1,000 live births) and relative change in age-specific mortality, Liberia, 0-4 years prior to the survey for 2007 and 2013 DHS

Age Category	Mortality (0-4 years prior to the survey)		% Relative change from 2007 to 2013
	2007 DHS (95 % CI)	2013 DHS (95% CI)	
Neonatal (NN)	32 (27-38)	26 (21-32)	-17.7%
Post-neonatal (PNN)	39 (33-48)	28 (23-33)	-30.0%
Infant ( $1q_0$ )	71 (63-82)	54 (47-61)	-24.5%
Child ( $4q_1$ ) <sup>a</sup>	41 (35-48)	42 (36-49)	2.6%
Under-five ( $5q_0$ )	109 (100-120)	94 (85-104)	-14.3%
1-59 months <sup>b</sup>	80 (71-89)	69 (61-78)	-13.5%
6-59 months <sup>c</sup>	60 (52-67)	55 (47-62)	-8.1%
6-23 months <sup>c</sup>	37 (31-44)	33 (28-40)	-9.5%
24-59 months <sup>d</sup>	24 (19-30)	22 (18-27)	-6.1%

<sup>a</sup> Child mortality ( $4q_1$ ) is per 1,000 live-born children surviving to 12 months of age

<sup>b</sup> 1-59 month mortality and 1-5 month mortality is per 1,000 live-born children surviving to 1 month of age

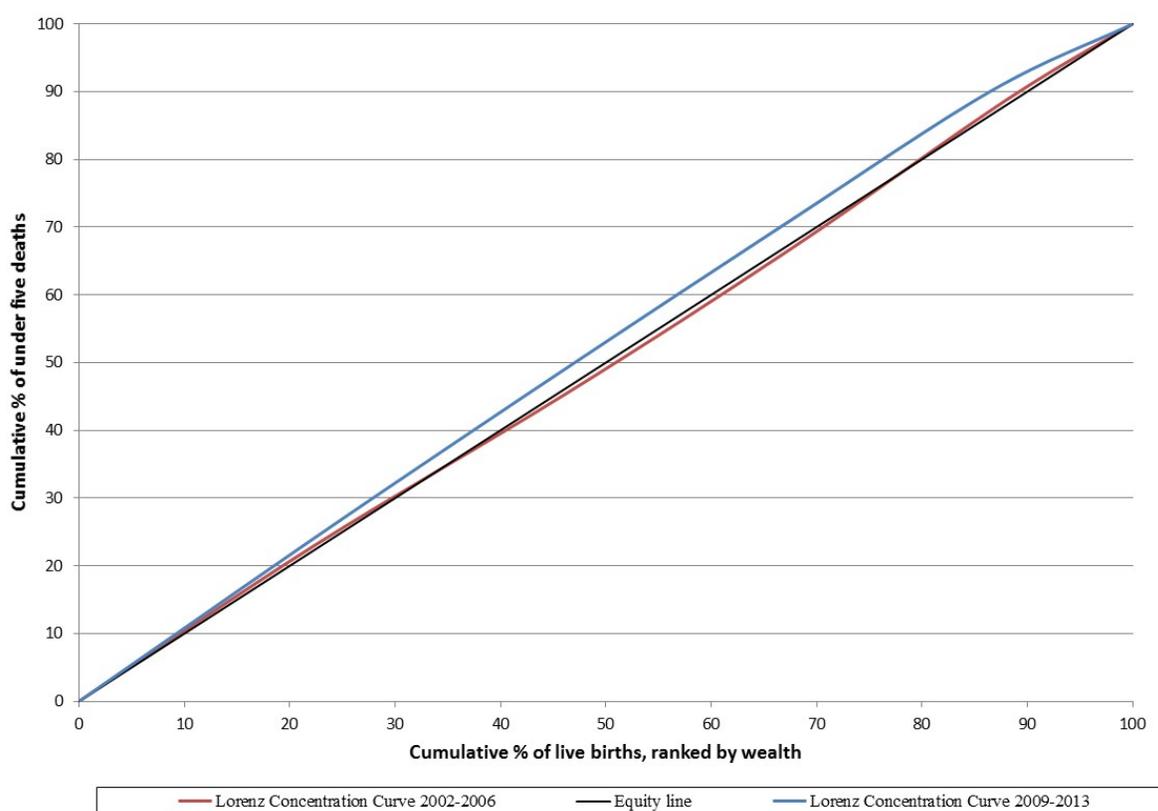
<sup>c</sup> 6-59 month mortality and 6-23 month mortality is per 1,000 live-born children surviving to 6 months of age

<sup>d</sup> 24-59 month mortality is per 1,000 live-born children surviving to 24 months of age

## Equity in ACCM

It is conceivable that mortality changes described in this section could have occurred through disproportionately large gains in higher socio-economic groups. If this were the case, the differential in mortality by wealth quintile would have widened over time. Inequalities in mortality by wealth quintile are presented here using Lorenz Concentration Curves – where the straight line represents perfect equality (with a concentration index of zero), and “upward” departure from the diagonal indicates higher mortality in poorer population quintiles (with a negative sign on the concentration index)<sup>17</sup>. Figure 23 shows the results of this analysis for ACCM estimates during the time periods 2002–2006 and 2009–2013. The concentration index in 2002–2006 (0.0015, 95% CI: -0.0564–0.0594) was slightly closer to “equality” than that from 2009–2013 (-0.0468, 95% CI: -0.1153–0.0217), however the results were not found to be statistically significant indicating that equity of child survival between households of different wealth quintiles did not change over the evaluation period.

Figure 24: Inequalities in ACCM in 2002–2006 and 2009–2013, DHS



<sup>17</sup> Concentration index values range between -1 and 1; a value of 0 suggests no difference among different socioeconomic groups.

ACCM estimates by socio-economic characteristics for the 2007 and 2013 DHS are presented in Table 22. ACCM among male children was slightly higher in the 2002–2006 period (118 deaths per 1,000 live births) compared to female children (101 deaths per 1,000 live births); however, there was no difference observed in the 2009–2013 time period. No significant differences were observed in ACCM by place of residence in either time period, though ACCM was slightly lower in urban areas in the 2009–2013 time period compared to rural areas and there was a greater relative decline in ACCM in urban areas compared to rural areas (19% and 10%, respectively). As shown in the Lorenz concentration index above, there were greater differences observed in ACCM by wealth quintile in the 2009–2013 period compared to the 2002–2006 period. In the 2009–2013 period, ACCM among the least poor was 69 deaths per 1,000 live births compared to poorest which was 102 deaths per 1,000 live births. The greatest relative decline in ACCM was also experienced among the least poor (33%); a 10% relative decline in ACCM was observed among the poorest between the two time periods. A similar trend was observed when assessing ACCM by mother’s education level. No difference is observed in ACCM among children whose mother received no education compared to children whose mother received a secondary or higher education in the 2002–2006 time period; however, ACCM was greater among children whose mother had no education in the 2009–2013 time period (102 deaths per 1,000 live births) compared to those that had a higher level of education (82 deaths per 1,000 live births). Overall, there were greater inequities observed in ACCM in the 2009–2013 time period compared to the 2002–2006 time period.

**Table 22: ACCM by sociodemographic characteristics, five-year estimates from the 2007 DHS and 2013 DHS**

Background Characteristics	2007 DHS			2013 DHS			Relative % change 2007 to 2013
	5q0	LCI	UCI	5q0	LCI	UCI	
<b>Sex</b>							
Male	117.5	101.7	133.0	94.1	80.8	107.1	-19.9
Female	101.0	86.9	114.9	93.5	79.9	106.9	-7.5
<b>Residence</b>							
Urban	110.1	93.3	126.6	89.1	72.6	105.4	-19.1
Rural	109.3	96.0	122.4	98.4	87.6	109.1	-10.0
<b>Wealth</b>							
Lowest	112.5	112.5	112.5	101.5	85.1	117.5	-9.9
Second	102.8	78.1	126.8	98.3	82.0	114.3	-4.4
Middle	109.7	85.8	133.0	96.2	73.7	118.0	-12.3
Fourth	118.2	93.0	142.8	93.5	60.3	125.6	-20.9
Highest	103.3	76.9	129.0	69.1	36.1	101.0	-33.1
<b>Mother's Education</b>							
None	105.1	89.7	120.2	100.2	85.9	114.3	-4.6
Primary	117.9	97.8	137.5	93.5	75.7	111.0	-20.6
Secondary or higher	105.7	74.3	136.1	82.2	61.3	102.6	-22.3
<b>Total</b>	109.5	99.0	119.8	93.8	84.1	103.3	-14.3

Notes: 5q0= under-five mortality; LCI= lower confidence interval; UCI= upper confidence interval

## Summary of All-cause Childhood Mortality and Malaria Mortality

Overall, ACCM declined from 109 to 94 deaths per 1,000 live births between 2002–2006 and 2009–2013 (14% relative decline), though the decline was not statistically significant. In assessing annual mortality trends, it is evident that there was not a consistent decline, but rather ACCM fluctuated over the evaluation period. When looking at mortality by the different age groups, the greatest relative declines between the two survey periods were among postneonates (30%) and infants (25%). Declines were observed in all age groups but child mortality (4q1); however, it was only significant among infants. Inequities in ACCM by place of residence, wealth, and mother's education level, were observed in the 2009–2013 period. Overall, ACCM demonstrated a larger relative decline in urban areas (19%) compared to rural areas (10%) between the two survey periods. Overall, the trends show a relatively small decline in mortality over the evaluation period, which was mostly due to declines in infant mortality.

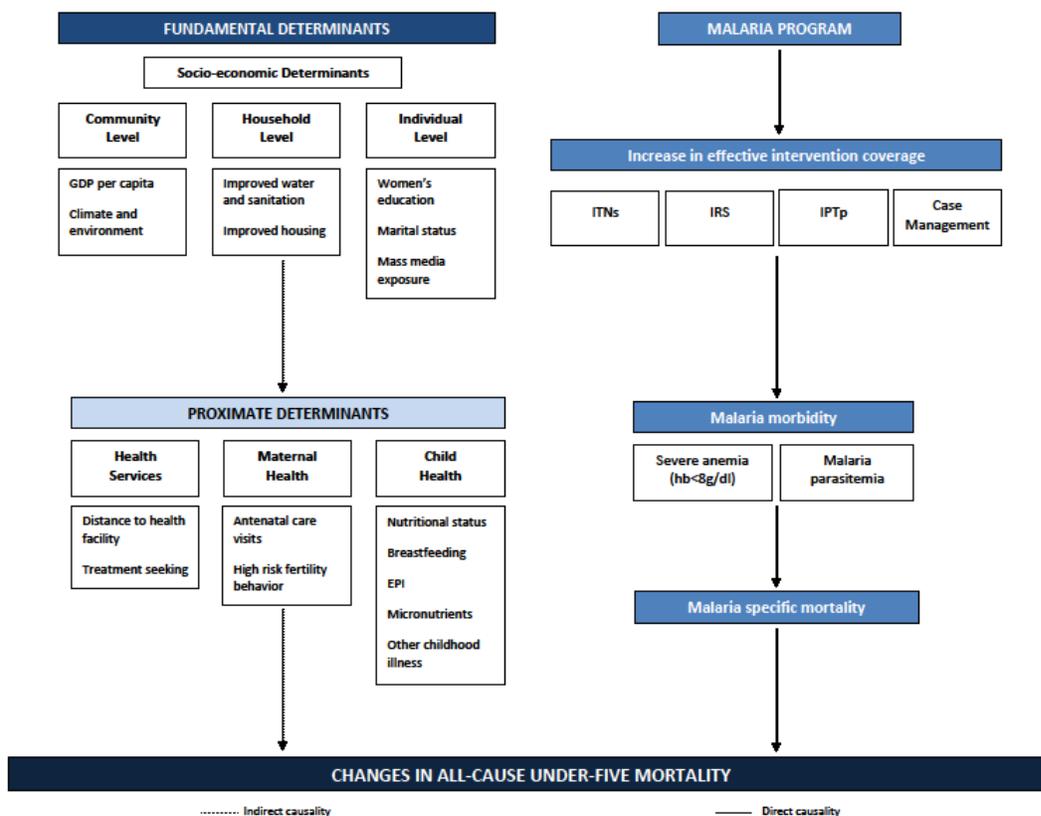
# CONTEXTUAL FACTORS

## Accounting for Contextual Factors

Appropriate consideration of contextual factors is essential to ensure the internal and external validity of evaluations of large-scale health programs [72], particularly for evaluations that are conducted when rapid changes are under way in many other aspects of health services [73].

Contextual factors associated with childhood mortality and illness, including malaria, can be broadly categorized into the fundamental and proximate determinants of disease [74-81]. Fundamental determinants are the social and economic conditions under which people live, while proximate determinants are biological risks. The conceptual framework [6, 73, 82, 83] for the evaluation design in Liberia, incorporates numerous contextual factors within various subcategories of the fundamental and proximate determinants of disease (Figure 28). In the following sections, relevant information and levels and trends on various contextual determinants – fundamental and proximate – of childhood mortality and illness are reviewed. Data on contextual factors were obtained from large population-based household surveys (including DHS, MIS, AIS, MICS), and other sources such as WHO, UNICEF, and the World Bank.

Figure 25: Conceptual framework for the evaluation of the malaria control program



## Fundamental Determinants

### Civil war

In 2003, Liberia emerged from 14 years of civil war. Out of an estimated population of 3.5 million, approximately 270,000 people died and more than 800,000 people were displaced [84]. The civil war destroyed much of the country's infrastructure, including roads and transport systems, schools, water and electricity, and the health system. At the end of the war, only 354 health facilities out of 550 remained operational. Of these, the majority of public health facilities were destroyed (242 out of 293 facilities). The majority of the doctors and many other health workers left the country; only 168 physicians remained in the country at the end of the war. Of the health providers that remained, most stayed in Monrovia leaving most of the population with little or no access to health care [85].

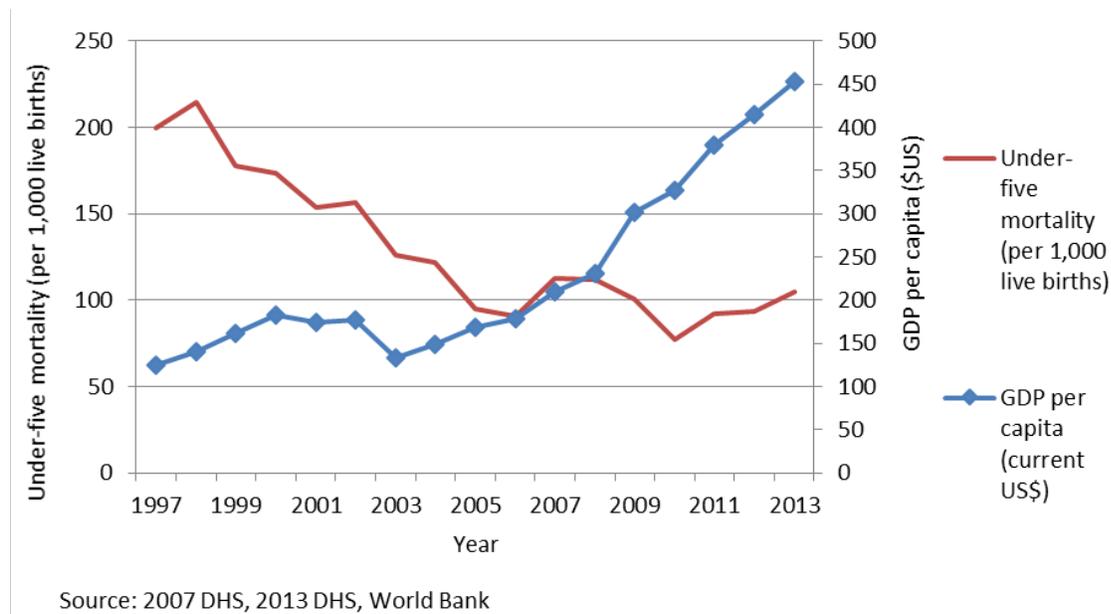
Liberia has been making steady progress since the end of the civil war to rebuild its infrastructure, and in particular, the health system. Government spending on health has gradually increased during this time and a significant amount of external assistance provided by donors has helped to invest in rebuilding the system. As of 2012, the number of operational health facilities had returned to the levels prior to the civil war, and training facilities for health providers were back up and running [86]. A National Health Policy, introduced in 2007, helped pave the way for recovery of the health system and put in place a plan to develop and implement a basic package of health services to all Liberians [23]. This policy was later followed by the launching of an EPHS in 2011 that broadened the scope of services provided in health facilities [25]. While substantial progress has been made since 2003, a number of barriers continue to challenge the health system. These include for example a chronic shortage of health workers; uneven access to health services across the country, particularly in rural areas; reoccurring drug and commodity stockouts; and funding and capacity shortfalls to deliver the EPHS in all health facilities [86].

### Socioeconomic factors

A range of socioeconomic determinants at the community, household, and individual level are associated with child survival [77, 87, 88], as shown in the impact model in Figure 27. Economic poverty, either at the country or individual level, strongly correlates with poorer health outcomes [89]. GDP per capita income, a measure of population wealth in a country, is considered to be a typical macroeconomic determinant of health [88]. The relationship between GDP per capita and ACCM indicates that a 1% annual increase in GDP per capita is associated with a 0.4-0.6% reduction in ACCM [90].

In Liberia, the GDP per capita (\$US) has risen from \$125 in 1997 to \$453 in 2013. Trends in GDP per capita and growth in Liberia are shown in Figure 29, in addition to annual estimates of ACCM. The GDP per capita gradually increased from 1997 to 2001 and then plateaued and dipped in 2003 at the end of the civil war. Post-civil war, the GDP has since been steadily increasing from 2003 to 2013.

Figure 26: Trends in GDP per capita and annual estimates of ACCM, Liberia, 1997– 2013



Alongside steady GDP growth, Liberia’s per capita health expenditure also gradually increased during the evaluation period, from \$13.3 per year in 2005 to \$41.2 in 2013 [91]. National health accounts data also show an almost two-fold increase in national institutional health expenditure during the evaluation time frame from \$65 million in the fiscal year 2007–08 to \$117.9 million in the fiscal year 2011-12 [92, 93].

Household and microeconomic factors are important determinants of child health and malaria risk [87, 94]. Socio-economic differentials at the household level are associated with access to malaria interventions [95-97], thereby increasing the vulnerability of the poorest to malaria [98]. Levels and trends in household attributes and other proxies of socio-economic status are summarized in Table 23.

Safe water and sanitary facilities contribute to improved child health and survival [95]. The proportion of households with an improved water source (i.e., protected, borehole, piped) slightly improved from 65% in 2007 to 73% and 2013. However, the proportion of households with a water source within 15 minutes of the household decreased significantly from 78% to 54% during this same time period. Household access to improved toilet facilities slightly improved from 10% in 2007 to 14% in 2013.

Housing construction, such as flooring and roofing material, has been used to assess household socioeconomic status; but house construction can also directly affect malaria risk [96, 97]. From 2007 to 2013, the proportion of household with modern floor materials (i.e., not earth, sand, or dung) slightly increased from 45% in 2007 to 53% in 2013.

Household access to electricity and a telephone (landline or mobile) improved significantly over the evaluation period. The proportion of households with electricity rose from 3% to 10%, while telephone access increased from 29% to 65% from 2007 to 2013.

**Table 23: Household attributes and asset ownership, Liberia, 2007–2013**

Indicator	2007 DHS		2009 MIS		2011 MIS		2013 DHS		% Relative Change 2007–2013	Sig
	% (95% CI)	WN								
Improved water source*, (% households)	65.2 (60.3-69.9)	6,824	74.5 (67.5-80.5)	4,162	72.1 (65.8-77.7)	4,162	72.6 (67.6-77.2)	4,162	11.3	NS
Time to water source <15 min, (% households)	77.7 (74.5-80.7)	6,824	n/a	n/a	63.3 (58.8-67.5)	4,162	54.2 (51.2-57.2)	4,162	-30.2	S
Improved toilet facilities**, (% households)	10 (8.1-12.3)	6,824	n/a	n/a	7.3 (5.4-9.8)	304	14.2 (11.8-16.9)	304	42.0	NS
Modern floor material (not earth/sand/dung), (% households)	44.8 (40.9-48.8)	6,824	47.4 (41.8-53.1)	4,162	55.5 (49.8-61)	4,162	53.4 (48.5-58.2)	4,162	19.2	NS
Electricity, (% households)	3 (2.1-4.3)	6,817	1.9 (1.2-2.9)	4,162	4.1 (2.6-6.2)	4,162	9.8 (7-13.6)	4,162	226.7	S
Telephone (landline or mobile), (% households)	28.7 (25.7-31.9)	6,817	43.2 (38.8-47.7)	4,162	54.1 (49.8-58.4)	4,162	64.6 (60.9-68.3)	4,162	125.1	S

Notes: \*Improved water source includes piped water into dwelling/yard/plot; public tap/standpipe, tube well or borehole, protected dug well, protected spring, or rainwater; \*\*Improved toilet facilities includes flush to piped sewer system, septic tank, or pit latrine, Ventilated improved pit (VIP) latrine, pit latrine with slab, and composting toilet. Information on sharing was not available. WN = Weighted Sample Size; CI = Confidence Interval; Sig.= Statistical significance; NS denotes not statistically significant; S denotes statistically significant.

## Weather variability

The weather in Liberia is tropical and humid, with little change in temperature throughout the year. The mean temperature is around 27°C and ranges from around 18°C in the northern highlands to a high of around 31°C. Malaria transmission in Liberia is characterized by seasonal trends, dependent on patterns of rainfall and temperature. In Liberia, the rainy season typically begins in May and continues through October, while the dry season begins in November and extends through April.

Mean minimum temperatures are particularly important for malaria transmission. Within the transmission season one of the primary limitations on transmission is low evening temperatures that slow parasite development within the vector. Higher minimum temperatures allow for greater degree-day time and more rapid parasite development within the vector. Maximum temperatures late in the dry season can in some areas reach levels where adult mosquito mortality occurs. In addition to annual seasonal fluctuations, inter-annual climatic drivers such as the El Niño Southern Oscillation can affect rainfall and temperature patterns in the region [99] within a given year, and longer-term patterns of climate change may influence rainfall and temperature patterns over many years or decades. It is important to consider and, where sufficient data exist, control for any inter-annual weather or longer-term climate trends when evaluating trends in malaria morbidity and mortality.

In Liberia, rainfall is heavier along the coast and decreases in areas that are farther inland. Annual rainfall ranges from about 200 cm in the inland areas to as high as 510 cm along the coast. In assessing historical trends in the country, the average annual temperature increased by 0.8 degrees Celsius since 1960 and the average annual precipitation has decreased since 1960. Figure 30 shows the mean historical monthly temperature and rainfall for Liberia from 1990-2012. The average monthly rainfall and average monthly temperature show substantial variations but with clear seasonal patterns [100]. Average annual rainfall precipitation during this same time period shows rainfall to be relatively stable [101].

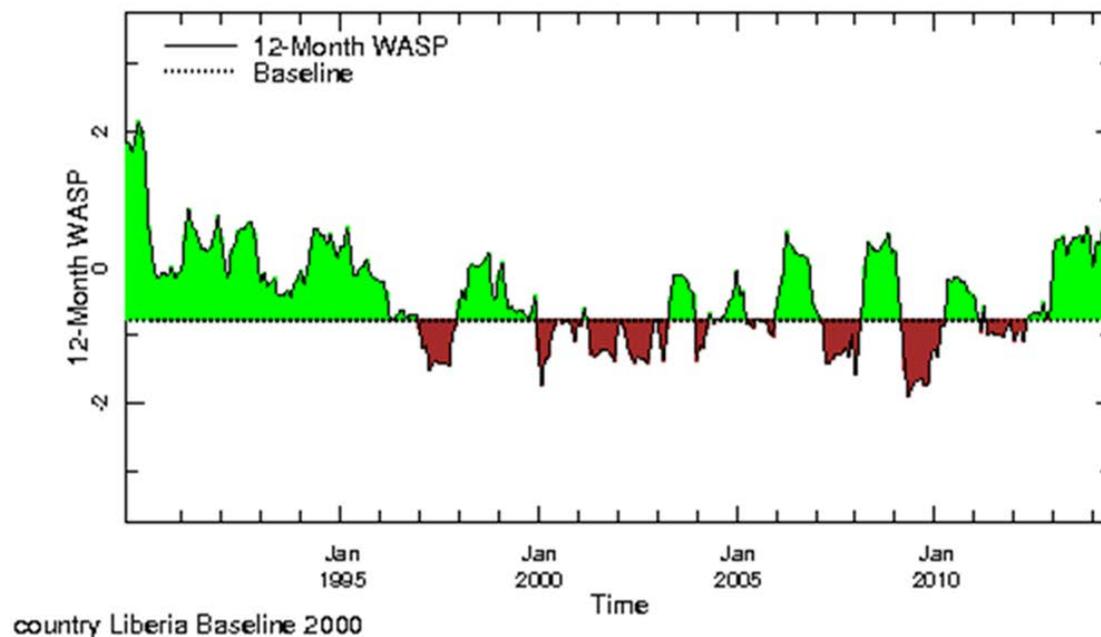
Figure 27: Average Monthly Temperature and Rainfall in Liberia, 1990-2012



Source: The World Bank

The 12-month Weighted Anomaly Standardized Precipitation (WASP)<sup>18</sup> data between January 1990 and January 2014 with the year 2000 as baseline, was reviewed to assess variations in rainfall in Liberia [102]. As shown in Figure 31, rainfall was generally above the WASP baseline during 1990–2014. Thus, rainfall patterns suitable for malaria transmission persisted throughout the evaluation period, and it is unlikely that any variations in rainfall could have altered malaria transmission during the evaluation period.

**Figure 28: 12-Month Weighted Anomaly Standardized Precipitation (WASP) Index, Liberia, 1990–2014**



### **Mother's Education and Marital Status**

At an individual level, maternal education is an important determinant of maternal and child health [88, 103-108]. In Liberia, maternal education slightly improved over the

---

<sup>18</sup> Weighted Anomaly Standardized Precipitation (WASP) index is an estimate of the relative deficit or surplus of precipitation for different time intervals ranging from 1 to 12 months and is based solely on monthly precipitation data. To compute the index, monthly precipitation departures from the long-term average are obtained and then standardized by dividing by the standard deviation of monthly precipitation. The standardized monthly anomalies are then weighted by multiplying by the fraction of the average annual precipitation for the given month. These weighted anomalies are then summed over varying time periods - here, 3, 6, 9 and 12 months. On the plots, the value of the given WASP index has itself been standardized. For the WASP index, shading starts at +/-1.0 with green shades indicating unusually wet conditions and brown unusually dry, respectively. Regions with an annual average precipitation of less than 0.2 mm/day have been "masked" from the plot. Source:

[http://ccnmtl.columbia.edu/projects/iri/responding/tutorial\\_frame\\_t3p2.html](http://ccnmtl.columbia.edu/projects/iri/responding/tutorial_frame_t3p2.html).

evaluation period. In 2007, 31% of women age 15-49 had completed primary school and 8% completed secondary school, compared to 39% completing primary and 10% completing secondary school in 2013. Women's literacy remained stable at about 40% in 2007 and 2009, and then rose significantly to 48% in 2013 (Table 24).

Survivorship and health outcomes of children under five years of age are better among married women [109-111]. In Liberia, however, there was a slight decline in the percent of women who married from 64% to 59%.

**Table 24: Education and marital status of women 15-49 years in Liberia, 2007–2013**

Indicator	DHS 2007		MIS 2009		MIS 2011		DHS 2013		% Relative Change 2003-2011	Sig
	% (95% CI)	WN								
Mean years of education	3.8 (3.6-4.1)	7,092	4.2 (3.7-4.7)	4,397	4.4 (4-4.8)	3,939	4.5 (4.1-4.8)	9,239	18.4	NS
Completed primary education (%)	30.7 (28.3-33.1)	7,092	31.9 (28.2-35.9)	4,397	38.4 (34.5-42.4)	3,939	39.1 (35.5-42.9)	9,239	27.4	S
Completed secondary education (%)	7.7 (6.7-8.9)	7,092	6.2 (4.8-7.9)	4,397	9.7 (7.6-12.2)	3,939	10.4 (8.6-12.4)	9,239	35.1	NS
Literacy (%)	40.8 (38-43.6)	7,092	39.6 (36-43.4)	4,397	n/a	n/a	47.9 (44.1-51.7)	9,239	17.4	S
Married (%)	64 (61.6-66.4)	7,092	n/a	n/a	n/a	n/a	58.3 (56.3-60.3)	9,239	-8.9	S

Notes: WN = Weighted Sample Size; CI = Confidence Interval; Sig.= Statistical significance. Statistics with non-overlapping 95% confidence intervals are considered significantly different. NS denotes not statistically significant and S denotes statistically significant.

## Proximate Determinants

### Maternal health

Antenatal care visits are considered a key entry point for a continuum of care during and after pregnancy that offer timely opportunities for receiving preventive and therapeutic interventions aimed at improving maternal, fetal, and newborn survival and wellbeing [112]. Through ANC, women benefit from counseling about healthy lifestyles, the provision of iron and folic acid supplements, and tetanus toxoid vaccinations to protect newborns against neonatal death in addition to malaria prevention interventions such as IPTp and distribution of ITNs. In Liberia, the percentage of women who attended four or more antenatal care visits (ANC4+) as recommended by WHO changed significantly over the evaluation period from 66% in 2007 to 78% in 2013 (Table 25).

Neonatal tetanus is often the result of infection from unhygienic cutting or cleaning of the umbilical cord at the time of delivery. To help prevent illness it is recommended for women who have never received the tetanus toxoid vaccine to receive a total of five doses: two doses given one month apart in the first pregnancy, then one dose in each subsequent pregnancy (or intervals of at least one year), to a total of five doses [113]. Maternal vaccination against tetanus creates antibodies that are passed to the child in utero thus providing protection in the first weeks of life [114]. A conclusive reduction in neonatal tetanus mortality has been demonstrated through the scale-up in tetanus vaccination of women of childbearing age [115]. In Liberia, the proportion of women whose most recent births (within the last two years) were protected against neonatal tetanus (two or more doses of tetanus toxoid vaccine) significantly increased from 75% in 2007 to 84% in 2013.

Vitamin A is also administered to women within 4-6 weeks after delivery, to ensure that vitamin A requirements are met postpartum and that the mother's milk contains sufficient vitamin A [116]. In Liberia, the percentage of women aged 15-49 with a live birth in the five years preceding the survey that received a high-dose vitamin A supplement within the first two months after birth remained relatively steady at around 62% during the evaluation period.

Child birth at health facilities, usually by skilled attendants, can reduce the chances of maternal and newborn complications. The percentage of births delivered at a health facility increased significantly from 37% in 2007 to 56% in 2013. Similarly, the percentage of births by a skilled attendant increased significantly from 46% to 61% from 2007 to 2013. Births in women with high-risk fertility<sup>19</sup> can increase the risk of early childhood mortality. From 2007 to 2009, births in any high-risk fertility category slightly increased from 59% to 62% but decreased to 58% in 2013. Similarly, births in women with unavoidable fertility risk<sup>20</sup> remained the same around 15% from 2007 to 2013.

---

<sup>19</sup> Births in women who are less than 18 years of age or greater than 34 years of age, births less than 24 months apart, and parity greater than 3.

<sup>20</sup> First order births to women between the ages of 18 and 34.

**Table 25: Maternal health in Liberia, 2007–2013**

Indicator	2007 DHS		2009 MIS		2011 MIS		2013 DHS		% Relative Change 2007-2013	Sig
	% (95% CI)	WN	% (95% CI)	WN	% (95% CI)	WN	% (95% CI)	WN		
ANC visits 4+ (% women, most recent live birth 0-2 yrs)	66 (61.7-70)	3,928	n/a	n/a	n/a	n/a	77.8 (75.5-79.9)	4,769	17.9	S
Tetanus toxoid 2+ (% women, most recent live births, 0-2 yrs)	74.6 (71-77.9)	3,928	n/a	n/a	n/a	n/a	84.1 (82-86)	4,769	12.7	S
Postnatal vitamin A supplementation	61.5 (56.8-66)	3,928	n/a	n/a	n/a	n/a	62.3 (59.1-65.5)	4,769	1.3	NS
Delivery at a health facility (% women, live births, 0-4 yrs)	36.9 (32.8-41.2)	5,594	n/a	n/a	n/a	n/a	55.8 (52.1-59.5)	6,502	51.2	S
Skilled attendant at birth	46.3 (41.5-51.1)	5,594	n/a	n/a	n/a	n/a	60.6 (56.9-64.1)	6,502	30.9	S
Births in any high-risk fertility category (%)**	59 (56.9-61)	5,594	61.8 (59-64.6)	4,027	n/a	n/a	57.4 (55.2-59.6)	6,502	-2.7	NS
Births with unavoidable fertility risk (%)*	15.8 (14.6-17.1)	5,594	14.3 (12.8-16)	4,027	n/a	n/a	15.6 (14.3-17)	6,502	-1.3	NS

Notes: \*First order births to women between the ages of 18 and 34; \*\*Births to women <18 and >34 and births <2 years apart; Sig.= Statistical significance. Statistics with non-overlapping 95% confidence intervals are considered significantly different change. NS denotes no statistically significant change and S denotes statistically significant change.

## Child health

The WHO Expanded Program on Immunization (EPI) offers vaccinations against common childhood communicable diseases and is one of the most cost-effective child survival interventions [117, 118]. Effective coverage of these vaccinations contributes substantially to reductions in ACCM. Liberia's recommended EPI schedule for children includes immunizations to protect against tuberculosis (BCG), polio, diphtheria, pertussis, and tetanus (DPT), hepatitis B (HBV), *Haemophilus influenzae b* (Hib), measles, and yellow fever [119]. The immunization schedule calls for BCG and the first dose of polio within 14 days after birth, DPT-HBV-Hib and polio at 6, 10, and 14 weeks after birth, and measles and yellow fever at or soon after 9 months of age [120]. The HBV and Hib antigens were added to the DPT vaccine in 2002. Recommendations call for complete immunizations before one year of age and specify that they should be recorded on an immunization card.

Coverage of each of these childhood vaccinations during 2007–2013, according to vaccination cards or mother's report during household surveys, is shown in Table 26. The proportion of children 12-23 months of age that received all of the recommended basic<sup>21</sup> vaccinations in the EPI schedule increased significantly from 39% to 55% from 2007 to 2013. All vaccines, individually, increased significantly from 2007 to 2013: BCG coverage increased from 77% to 94%, coverage of three doses of DPT-HBV-Hib increased from 50% to 71%, coverage of three doses of polio increased from 50% to 70%, and measles vaccination increased from 63% to 74%. Coverage of yellow fever in 2013 was 73% (not shown in table since no additional data is available).

Acute respiratory infections (ARI) and diarrheal diseases, caused by a variety of viral and bacterial pathogens, are among the leading causes of illness and death in children under five years of age, both globally and in Liberia. Interventions to control these two diseases mainly include immunizations against specific pathogens, early diagnosis and treatment, community case management through community health workers, improvements in nutrition and feeding practices, and improvements in access to safe drinking water, sanitation, and indoor air pollution. Data on the prevalence and treatment seeking practices of these two conditions were collected during household surveys in Liberia by asking mothers whether their children under five years of age had been ill with a cough accompanied by short, rapid breathing and whether they suffered from diarrhea in the two weeks preceding the survey. The percentage of children under five years of age who were ill with symptoms of ARI (cough and rapid breathing) two weeks preceding the survey remained relatively stable over the evaluation period; declining slightly from 9% in 2007 to 7% in 2013. Care-seeking for children with symptoms of ARI remained stable during the evaluation period (62% and 64% in 2007 and 2013, respectively). During the two weeks preceding the survey, 20% of children under five years of age had diarrhea in 2007 compared to 22% in 2013. Care-seeking for children with diarrhea increased slightly from 49% to 58% from 2007 to 2013. The percentage of children under five years of age with

---

<sup>21</sup> Basic vaccinations include BCG, measles, three doses of DPT and polio vaccine. Yellow fever is not included in the basic vaccination package.

diarrhea in the two weeks preceding the survey that used oral rehydration salts (ORS) increased slightly from 53% in 2007 to 60% in 2013.

**Table 26: Child health in Liberia, 2007–2013**

Indicator	2007 DHS		2013 DHS		% Relative Change 2007-2013	Sig
	% (95% CI)	WN	% (95% CI)	WN		
BCG	77.1 (70.7-82.4)	977	93.9 (91.9-95.4)	1,272	21.8	S
DPT3/Pentavalent 3	50.3 (44.6-55.9)	977	71.4 (67.3-75.2)	1,272	41.9	S
Polio3	49.4 (44.2-54.7)	977	69.9 (65.8-73.7)	1,272	41.5	S
Measles	63 (57.2-68.5)	977	74.2 (70.6-77.5)	1,272	17.8	S
All (BCG, measles, DPT3, polio3)	39 (34.2-44.1)	977	54.8 (50.8-58.8)	1,272	40.5	S
Children 0-4 yrs had ARI symptoms in previous 2 weeks*	8.6 (7.2-10.1)	440	6.5 (5.6-7.6)	6,047	-24.4	NS
Children 0-4 yrs with ARI sought treatment	62.2 (56-68)	440	64 (57.1-70.5)	396	2.9	NS
Children 0-4 yrs with diarrhea in previous 2 weeks	19.8 (17.8-21.8)	5,132	22 (20.4-23.7)	6,047	11.1	NS
Children 0-4 yrs with diarrhea sought treatment	49.3 (43.6-55.0)	1,014	58.1 (53.8-62.3)	1,330	17.8	NS
Children 0-4 yrs with diarrhea used ORS	53.1 (48.4-57.8)	1,014	60.4 (56.6-64.1)	1,330	13.7	NS

Notes: \*The definition of ARI used is whether the child had with cough in past two weeks and if he/she breathed faster than usual with short, fast breaths; Sig.= Statistical significance. Statistics with non-overlapping 95% confidence intervals are considered significantly different. NS denotes not statistically significant and S denotes statistically significant

### Breastfeeding practices and undernutrition in children and women

In addition to serving as a source of nutrition, breastfeeding during infancy provides protection against infectious diseases, including diarrhea and ARI, the leading causes of ACCM [80, 121]. Early and exclusive breastfeeding is an important child survival intervention which reduces neonatal, infant, and child mortality [122]. Currently, the WHO recommends early and exclusive breastfeeding for the first six months following birth [123]. In Liberia, 30% of children less than six months of age were exclusively breastfed in 2007, as compared to 55% in 2013, a significant increase (Table 27). However, the proportion of children age 6-9 months who were breastfed and consumed complementary foods declined significantly from 63% in 2007 to 42% in 2013.

Undernutrition due to chronic dietary deficiency of protein, energy, essential vitamins, and minerals (collectively referred to as micronutrients) is an important determinant of maternal and child health [124]. The continuum of maternal, fetal, and child undernutrition results in 3.5 million preventable child and maternal deaths globally, per year [121]. In children under five years of age, the standardized anthropometric measures of undernutrition are a) low birth weight due to intrauterine growth restriction (IUGR); b) underweight, a reflection of low weight-for-age; c) stunting, a chronic restriction of growth in height indicated by a low height-for-age; and d) wasting, an acute weight loss indicated by a low weight-for-height. Undernutrition prevalence in children under five years of age was measured in the 2007 and 2013 DHS surveys (Table 28). The DHS also collects information on children's birthweight as recorded in health cards and by mother's recall. The proportion of children born with a low birthweight (<2500g) as measured by the health card or by mother's recall declined slightly over the evaluation period, from 12% in 2007 to 10% in 2013. The percentage of children under five years of age reported as stunted declined significantly from 39% in 2007 to 32% in 2013. The percentage of children under five years of age reported as underweight also declined significantly from 19% in 2007 to 15% in 2013. Similarly, the percentage of children under five years of age that are wasted decreased slightly from 8% in 2007 to 6% in 2013.

Vitamin A deficiency has been implicated in increased morbidity and mortality from infectious diseases such as measles, diarrhea, and acute respiratory infections, and results in up to 600,000 deaths of children under five years of age annually world-wide [121]. Depletion of stored vitamin A occurs over a period of four to six months, when the diet contains too little replacement. Periodic vitamin A supplementation every six months in areas with prevalent pre-existing vitamin A deficiency has been shown to replenish vitamin A stores needed for essential physiological functions and to decrease ACCM by up to 23% [125, 126]. In Liberia, vitamin A supplementation improved significantly over the evaluation period. In 2007, 42% of children age 6-59 months received a vitamin A supplement in the six months prior to the survey compared to 60% in 2013.

**Table 27: Breastfeeding and undernutrition in children and women in Liberia, 2007–2013**

Indicator	2007 DHS		2013 DHS		% Relative Change 2007–2013	Sig
	% (95% CI)	WN	% (95% CI)	WN		
Exclusive breastfeeding in children <6 months of age (%)	29.1 (23.8-35.1)	486	55.2 (49.6-60.7)	590	89.7	S
% of children 6-9 months breastfeeding and consuming complementary foods	62.2 (55.7-68.4)	382	42.2 (35.8-48.9)	409	-32.2	S
Low birth weight <2500 g (%)	11.6 (8.7-15.4)	5,594	9.7 (7.9-11.9)	1,510	-16.4	NS
Under-fives stunted (%)*	39.4 (37.5-41.4)	5,166	31.6 (29.3-34)	3,520	-19.8	S
Under-fives underweight (%)*	19.2 (17.4-21.1)	5,166	15 (13.5-16.7)	3,520	-21.9	S
Under-fives wasted (%)*	7.5 (6.4-8.6)	5,166	6 (5-7.3)	3,520	-20.0	NS
Vitamin A supplementation within past 6 months (% children 6-59 months)	41.9 (38.2-45.6)	4,635	60.1 (56.5-63.6)	5,444	43.4	S

Notes: \* Definitions and methods per WHO reference population; Sig.= Statistical significance. Statistics with non-overlapping 95% confidence intervals are considered significantly different change. NS denotes no statistically significant change and S denotes statistically significant change.

### HIV/AIDS among children and women

The advent of the HIV/AIDS epidemic in the 1980s, threatened child survival gains made globally since the 1960s [127]. Child survival stagnated and even reversed in many countries in sub-Saharan Africa [128] and HIV/AIDS was found to be an increasingly important cause of ACCM in Sub-Saharan Africa [129].

In Liberia, the first case of HIV infection was reported in 1986 [130]. Due to the long civil war beginning in 1989, little was known about HIV prevalence and its spread until the end of the civil war in 2004. Overall, HIV prevalence among the general adult population is low and remained stable across the evaluation period. In 2007, an estimated 1.5% of adults 15-49 years of age were infected with HIV, and in 2013, 1.9% were infected (there was no statistically significant difference between the two estimates) [131, 132]. While coverage of prevention of mother-to-child transmission (PMTCT) during pregnancy and of antiretroviral treatment (ART) have improved over the evaluation period, most

improvements occurred during the end of the evaluation period. The percentage of HIV-positive pregnant women that received ART to reduce the risk of mother-to-child transmission was 18% in 2010, and increased to 64% in 2013; while ART coverage for eligible adults and children was 22% in 2010 and only 38% by 2013 [133].

## Summary of contextual factors

Liberia has experienced a number of positive developments during the evaluation period, some of which would be expected to lead to improved child survival. A summary of these changes and the expected relationship with ACCM in Liberia is presented in Table 28.

Table 28: Summary of changes in factors that could be associated with ACCM in Liberia, 2007–2013

	Evidence supporting lower mortality	No evidence suggesting change in mortality	Evidence supporting higher mortality
Malaria control interventions	<ul style="list-style-type: none"> <li>Household ownership of ITNs</li> <li>ITN use by children under-five</li> <li>IRS (in selected areas)</li> <li>IPTp</li> <li>Use of ACTs</li> </ul>	<ul style="list-style-type: none"> <li>ITN use by pregnant women</li> <li>ITN use by general population</li> <li>Care-seeking for fever</li> </ul>	
Other contextual determinants	<p><b>Fundamental determinants</b></p> <ul style="list-style-type: none"> <li>Overall improvements in health system post-civil war</li> <li>GDP per-capita growth</li> <li>National per-capita health expenditure</li> <li>Asset ownership (telephone access) and housing conditions (electricity)</li> <li>Women’s education and literacy</li> </ul> <p><b>Proximate determinants</b></p> <ul style="list-style-type: none"> <li>Antenatal care attendance</li> <li>Tetanus toxoid vaccination</li> <li>Delivery at a health facility and with a skilled attendant</li> <li>BCG, DPT3, polio, and measles vaccinations</li> <li>Vitamin A supplementation for children 6-59 months</li> <li>Exclusive breastfeeding</li> <li>Nutritional status (stunting, underweight)</li> </ul>	<p><b>Fundamental determinants</b></p> <ul style="list-style-type: none"> <li>Weather conditions</li> <li>Housing conditions (improved water source and toilet facilities, flooring material)</li> <li>Women married</li> </ul> <p><b>Proximate determinants</b></p> <ul style="list-style-type: none"> <li>Postnatal vitamin A supplementation</li> <li>Proportion of births that are high risk or with unavoidable fertility risk</li> <li>ARI prevalence and care-seeking</li> <li>Diarrhea prevalence, care-seeking and treatment</li> <li>Low birth weight prevalence</li> <li>Nutritional status (wasting in children under five years old)</li> <li>HIV prevalence, ART and PMTCT coverage</li> </ul>	<p><b>Fundamental determinants</b></p> <ul style="list-style-type: none"> <li>None</li> </ul> <p><b>Proximate determinants</b></p> <ul style="list-style-type: none"> <li>Breastfeeding and consumption of complementary foods for children 6 to 9 months of age</li> </ul>

In addition to some of the improvements observed in the malaria control interventions, other favorable changes occurred in other fundamental and proximate determinants during the evaluation period. Overall improvements in the health care system were made after the civil war, with large investments in rebuilding the infrastructure and training of health providers during the evaluation period, ultimately increasing access to health care services. GDP per-capita and national health expenditure per capita steadily increased, access to telephones and electricity improved, the proportion of women with at least a primary school education rose significantly as did literacy among women. Significant improvements were made in a number of maternal and child health interventions, including: ANC attendance; coverage of tetanus toxoid vaccination during pregnancy; delivery at a health facility and with a skilled attendant; vaccination coverage of BCG, DTP, polio and measles; and postnatal vitamin A supplementation and vitamin A supplementation for children 6-59 months of age. Additionally, significant improvements were observed in exclusive breastfeeding coverage and in child nutritional status, with reductions observed in both stunting and underweight prevalence.

Only one key contextual factor changed in a direction that would be expected to favor higher mortality, or congruently, favor slower declines in mortality among children under five years of age. The coverage of breastfeeding and consumption of complementary foods for infants 6-9 months of age declined significantly during the evaluation period. Many contextual factors remained unchanged over the evaluation period, including weather conditions, housing conditions (specifically access to an improved water source and toilet facilities, and flooring material), and the proportion of women that got married. Furthermore, ARI and diarrhea prevalence remained unchanged, as did care-seeking for ARI and diarrhea, treatment for diarrhea (ORS), the proportion of births that are high-risk or have unavoidable fertility risk, low birth weight prevalence, and HIV prevalence and treatment (PMTCT and ART) coverage.

# FURTHER ANALYSES

## Multiple Logistic Regression Analysis

### Background

The purpose of the multiple logistic regression analysis was to examine the relationship between household ITN ownership and malaria parasitemia, adjusting for potential confounders. The question examined was: Is household ITN ownership protective against malaria parasite infection under programmatic conditions in Liberia after controlling for potential confounders?

Household ITN ownership was selected instead of ITN use (among children under five years of age) the night before the survey since it covers a longer period of time and is therefore more likely to intersect with the timing of malaria parasite infection. We examined the relationship between malaria parasitemia and whether a household owned at least one ITN or not and household ITN ownership by the age of the net. We defined the age of the net based on the timing of when a net was obtained and categorized length of net ownership into four categories: no ITN and ITN owned between 0-6 months, 7-12 months, or greater than 12 months. ITNs that were only recently obtained may have not been in use when a child first got malaria, since the incubation period of the disease may take a few weeks to show a positive test result. Conversely, ITNs that had been owned for a longer period of time could be less protective due to wear-and-tear of the net, or a reduction in efficacy of the insecticide.

### Model-building Process

Using data from the 2011 MIS, we assessed the cross-sectional relationship between malaria parasitemia (via RDT) in children under five years of age and household ownership of an ITN, household ownership of an ITN stratified by the age of the net, and other essential demographic factors in Liberia. Demographic variables anticipated to be associated with ITN ownership were selected based on prior published literature and availability within the MIS survey framework [134-138]. All analyses were conducted using Stata 14 and a significance level of 0.05.

First, we examined the unadjusted bivariate association between each predictor variable and malaria parasitemia. Second, we separately examined the association for two explanatory variables of interest (household ownership of at least one ITN and household ownership of an ITN stratified by age of the net), adjusting for potential confounding variables of interest selected based on those variables hypothesized to both influence parasitemia and ITN ownership. The covariate factors included: age of child (6-23 months and 24-59 months), sex of child, mother's education level, region of the country, whether the household had been sprayed (IRS) in the past 12 months, place of residence (urban/rural), malaria risk (defined as below 40% and 40% and above  $PfPR_{2-10}$ ), wealth quintiles, and number of household members. Correlations between the selected variables (the predictor variables and the eight covariates) were checked for collinearity and interaction. All of the nine variables were retained, since none were highly correlated with

another (that is, at a level greater than 0.6). A significant interaction was found between place of residence and malaria risk area.<sup>22</sup>

## Results from the Logistic Regression Models

The final results of the two logistic regression models are found in Table 29 and 30.

**Table 29: Multiple logistic regression model: The effect of ITN ownership on malaria parasitemia (via RDT) in children under five years of age**

Characteristic	N	Parasitemia prevalence (%)	Adjusted OR (95% CI)	P-value
<b>Total</b>	1,752	44.9		
<b>Household ITN Ownership</b>				
No ITN	810	47.8	1.00 (reference)	
Owns at least one ITN	942	42.4	0.84 (0.69, 1.04)	0.103
<b>Sex of Child</b>				
Male	901	46	1.00 (reference)	
Female	851	43.7	0.96 (0.78, 1.17)	0.659
<b>Age of Child</b>				
6-23 months	543	29.8	1.00 (reference)	
24-59 months*	1,210	51.6	2.87 (2.29, 3.60)	0.000
<b>Mother's Education in Years</b>				
No formal education	830	51.7	1.00 (reference)	
Primary education	517	46.7	0.87 (0.69, 1.09)	0.230
Secondary or higher*	406	28.7	0.74 (0.55, 0.99)	0.042
<b>Region</b>				
Monrovia	375	15.7	1.00 (reference)	
North Western	157	48.8	1.06 (0.56, 2.01)	0.860
South Central*	348	50.9	1.78 (1.03, 3.07)	0.040
South Eastern A	152	57.1	1.33 (0.67, 2.64)	0.423
South Eastern B*	125	71	2.27 (1.14, 4.51)	0.020
North Central	595	50.1	1.15 (0.61, 2.18)	0.667
<b>Had household IRS in last 12 months</b>				
No	1,609	44.2	1.00 (reference)	
Yes	143	52.7	1.22 (0.80, 1.87)	0.354
<b>Place of Residence</b>				
Urban	717	29.5	1.00 (reference)	
Rural*	1,035	55.6	2.62 (1.66, 4.15)	0.000
<b>Malaria Risk P/PR<sub>2-10</sub></b>				
<40%	964	34.8	1.00 (reference)	
≥40%*	788	57.2	3.99 (2.32, 6.86)	0.000
<b>Wealth</b>				
Highest	229	11.9	1.00 (reference)	
Fourth*	316	33.4	2.10 (1.24, 3.55)	0.006
Middle*	345	50.5	3.26 (1.92, 5.51)	0.000
Second*	413	55.7	2.99 (1.74, 5.11)	0.000
Lowest*	449	55.6	2.81 (1.61, 4.89)	0.000

<sup>22</sup> The full model results with the interaction term can be found in the report appendices.

**Number of Household Members**

1-3	235	38.1	1.00 (reference)	
4-6	856	44.9	0.92 (0.67, 1.26)	0.585
7+	662	47.3	0.97 (0.70, 1.34)	0.837

Notes: The model was restricted to one child under-five years per household to avoid cluster effects; \*p < 0.05; 95% CI = 95% Confidence Interval.

The final multiple logistic regression model that examined the relationship between malaria parasitemia and household ownership of an ITN (Table 29), consisted of eleven independent variables: the main predictor, household ITN ownership, and nine covariates. Six of the variables were found to be significantly associated with malaria parasitemia prevalence in children 6-59 months of age.

Household ownership of an ITN showed a protective effect for malaria parasitemia in children, with the odds of parasitemia 16% lower in children from households that owned at least one ITN compared to children from households that did not have an ITN, though this effect fell just short of statistical significance (AOR= 0.84, 95% CI: 0.69-1.04). Age of the child was found to be significantly associated with malaria parasitemia, with older children (24-59 months) 2.9 times (AOR=2.83, 95% CI: 2.29 -3.60) more likely to have malaria parasitemia compared to children 6-23 months of age. Mother's education level was significantly associated with parasitemia prevalence, with children whose mother had a secondary or higher level of education 26% less likely to have malaria parasitemia compared to children whose mother had no education (AOR=0.74, 95% CI: 0.55-0.99). The region of the country was also significantly associated with parasitemia prevalence, with children from the regions of South Central and South Eastern B significantly more likely to have malaria parasitemia compared to children from Monrovia. The greatest odds of malaria parasitemia were found among children from South Eastern B. Children from South Eastern B region were 2.3 times more likely to be infected compared to children from Monrovia (AOR =2.27, 95% CI: 1.14-4.51). Children from rural households were 2.6 times (AOR=2.62, 95% CI: 1.66-4.15) more likely to have malaria parasitemia than children from urban households. Children living in higher malaria risk areas ( $\geq 40\%$ ) were approximately 4 times more likely to have malaria parasitemia compared to those in the lower/medium risk areas (AOR=3.99, 95% CI: 2.32-6.86). Lastly, household wealth was also found to be significantly associated with malaria parasitemia. Children from households in the lowest through fourth quintiles, were all significantly more likely to have malaria parasitemia compared to children in the highest quintile. Sex of the child, whether the household had IRS in the previous 12 months, and household size were not found to be significantly associated with malaria parasitemia.

**Table 30: Multiple logistic regression model: The effect of ITN ownership by age of net on malaria parasitemia (via RDT) in children under five years of age**

Characteristic	N	Parasitemia prevalence (%)	Adjusted OR (95% CI)	P-value
<b>Total</b>	<b>1,752</b>	<b>44.9</b>		
<b>ITN Net Ownership by Age of Net^</b>				
No ITN	810	47.8	1.00 (reference)	
ITN owned 0-6 months*	173	35.4	0.69 (0.48, 0.98)	0.040
ITN owned 7-12 months	221	39.8	0.88 (0.64, 1.22)	0.449
ITN owned >12 months	247	53.7	1.19 (0.87, 1.63)	0.285
<b>Sex of Child</b>				
Male	901	46.0	1.0 (reference)	
Female	851	43.7	0.98 (0.78, 1.23)	0.864
<b>Age of Child</b>				
6-23 months	543	29.8	1.00 (reference)	
24-59 months*	1,210	51.6	2.79 (2.17, 3.57)	0.000
<b>Mother's Education in Years</b>				
No formal education	830	51.7	1.00 (reference)	
Primary education	517	46.7	0.85 (0.66, 1.11)	0.233
Secondary or higher*	406	28.7	0.70 (0.51, 0.97)	0.030
<b>Region</b>				
Monrovia	375	15.7	1.00 (reference)	
North Western	157	48.8	0.93 (0.46, 1.87)	0.842
South Central	348	50.9	1.69 (0.93, 3.07)	0.084
South Eastern A	152	57.1	1.27 (0.60, 2.72)	0.533
South Eastern B	125	71	2.11 (0.99, 4.50)	0.054
North Central	595	50.1	1.14 (0.57, 2.30)	0.707
<b>Had household IRS in last 12 months</b>				
No	1,609	44.2	1.00 (reference)	
Yes	143	52.7	1.36 (0.83, 2.21)	0.219
<b>Place of Residence</b>				
Urban	717	29.5	1.00 (reference)	
Rural*	1,035	55.6	2.86 (1.73, 4.74)	0.000
<b>Malaria Risk PfPR<sub>2-10</sub></b>				
<40%	964	34.8	1.00 (reference)	
≥40%*	788	57.2	3.90 (2.14, 7.11)	0.000
<b>Wealth</b>				
Highest	229	11.9	1.00 (reference)	
Fourth*	316	33.4	2.99 (1.61, 5.55)	0.001
Middle*	345	50.5	3.63 (1.94, 6.78)	0.000
Second*	413	55.7	3.07 (1.62, 5.83)	0.001
Lowest*	449	55.6	2.84 (1.47, 5.48)	0.002
<b>Number of Household Members</b>				
1-3	227	38.1	1.00 (reference)	
4-6	751	44.9	0.89 (0.64, 1.25)	0.514
7+	563	47.3	1.02 (0.71, 1.45)	0.918

---

Notes: The model was restricted to one child under-five years per household to avoid cluster effects; ^ Due to insufficient cases (n=9) for age of net between 0-1 months, we lumped 0-6 months together. \*p < 0.05; 95% CI =

The final multiple logistic regression model that examined the relationship between malaria parasitemia and household ITN ownership by age of net (Table 30), consisted of eleven independent variables: the main predictor, household ITN ownership by age of net, and nine covariates. Household ITN ownership by age of net was found to be significantly associated with malaria parasitemia. In households where the ITN had been acquired between 0-6 months before the survey, children had a 31% lower odds of malaria parasitemia compared to children from households with no ITN (OR = 0.69 [95% CI: 0.48–0.99]). This protective effect however was no longer significant in households that owned ITNs for 7 to 12 months. This lack of a significant protective effect could be an indication that ITN's older than 6 months were not in as good condition (for example, they could have had more holes). It could also be an indication of a decline in the novelty factor; that is, ITNs are used more when they are first acquired but over time are used less due to loss of interest. Furthermore, the longer a household has owned an ITN, the more likely there might be errors of recall in relation to the reported age.

Similar to the first model, a significant association was found between malaria parasitemia infection and the age of child, mother's education level, place of residence, malaria risk, and household wealth quintile. No significant relationship was found between malaria parasitemia and sex of the child, region, whether the household had IRS in the previous 12 months, or household size.

# **PLAUSABILITY ANALYSIS AND CONCLUSION**

## PLAUSABILITY ANALYSIS AND CONCLUSION

In this section, the expansion of malaria control intervention coverage and changes in malaria related outcomes in Liberia are summarized, and the plausibility that the expansion of malaria interventions led to changes in malaria-related outcomes and impact during the evaluation period is assessed. To determine whether the expansion of malaria control interventions could have contributed to the observed decline in ACCM, and specifically to the significant decline observed in infant mortality, and if so, to what extent, we examined the fundamental and proximate determinants of child mortality that were in the causal pathways of the conceptual framework (Figure 27).

### Coverage of malaria control interventions has improved

Household ownership of at least one ITN increased<sup>23</sup> from 18% to 55% nationwide between 2005 and 2013, with greater improvement observed in rural areas (61% by 2013) compared to urban areas (50% by 2013). The percentage of the de facto population with “access” to an ITN rose from 16% in 2007 to 36% in 2013. ITN use among the general population rose slightly from 24% in 2009 to 32% in 2013 (no data were available from the beginning of the evaluation period). ITN use among children under five years of age rose from 2% in 2005, to 26% in 2009, and then to 38% by 2013, while ITN use among pregnant women only slightly increased from 33% in 2009 to 37% in 2013. No significant differences were found in ITN use among children under five years of age by sex, place of residence or mother’s education level; similarly, no differences were found in ITN use among pregnant women by place of residence or education level. However, ITN use among children under five years of age and pregnant women was overall higher in the poorer households compared to the least poor households at the end of the evaluation period. Overall, household ownership of one or more ITNs grew steadily during the evaluation period, however household access to an ITN (defined as one ITN for every two people in the household) only reached 22% by 2013, indicating that a large gap remained in achieving universal coverage of ITNs.

National IRS coverage measured through the 2011 MIS and the 2013 DHS remained stable at 9% and 11%, respectively; while coverage of households with at least one ITN and/or IRS in the last 12 months slightly increased from 54% in 2011 to 59% in 2013.

Implementation of IPTp began in Liberia in 2005. Coverage with two doses increased significantly over the evaluation period from 4% in 2005 to 48% in 2013; however, it is important to note that IPTp coverage did remain stable during the latter half of the evaluation period from 2009 to 2013 (45% to 48%). Slight disparities were observed in IPTp coverage by place of residence, wealth, and education level; however, these were not consistent across all survey years and were not statistically significant. While IPTp coverage improved substantially over the evaluation period, this improvement likely had minimal impact on ACCM during the evaluation period and is unlikely to have impacted the parasitemia and severe anemia prevalence estimates in children 6–59 months of age.

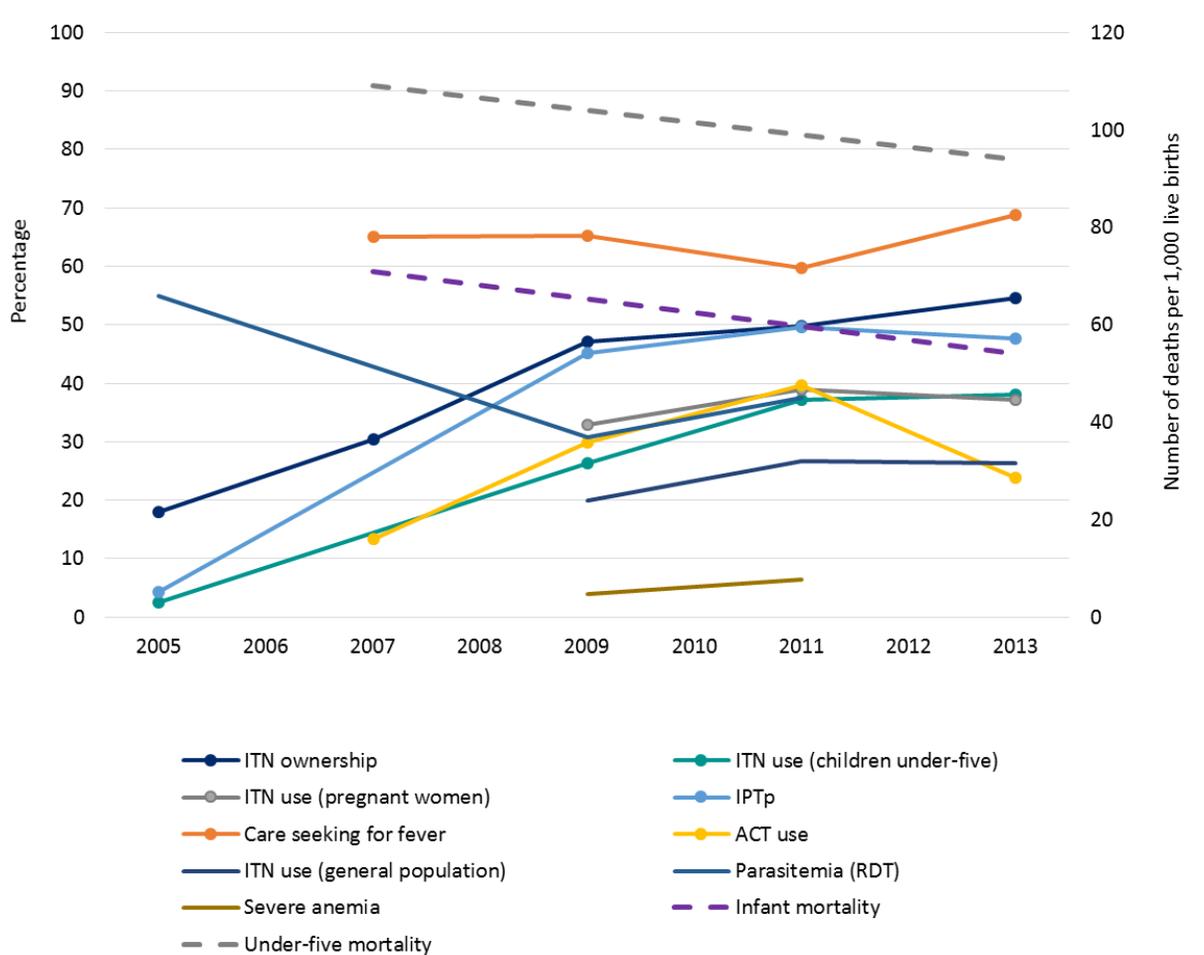
---

<sup>23</sup> The 2005 MIS and 2007 DHS estimates reflect household ownership of any bednet. ITN ownership was not measured in either survey.

Care-seeking for fever from formal health providers in children under five years of age remained relatively stable over the evaluation period, ranging from 60% to just under 70%. Significant disparities in care-seeking for fever were observed by place of residence, mother’s education level, and wealth quintile across the evaluation period. Treatment with any antimalarial drug for children with fever in the previous two weeks also remained stable over the evaluation period (59% in 2007 to 56% in 2013); however, treatment with first-line antimalarial drugs showed a substantial improvement from 13% in 2003 to 40% in 2011. Coverage then declined in 2013, however this decline should be interpreted with caution as it is likely biased downwards due to issues with recall bias during the survey. Diagnostic testing for malaria also increased from 24% in 2009 to 42% in 2013.

While coverage of all malaria control interventions did improve over the evaluation period, all interventions remained well below the national targets for coverage. A summary of trends in malaria intervention coverage and ACCM and infant mortality are depicted in Figure 32.

**Figure 29: Summary of trends in malaria control interventions and ACCM and infant mortality, 2005–2013**



Source: 2005 MIS report, 2007 DHS, 2009 MIS, 2011 MIS, and 2013 DHS

## **Malaria-related morbidity**

Malaria parasitemia prevalence among children 6-59 months measured through RDTs, declined substantially from 66% in 2005 to 37% in 2009, but then increased significantly to 45% in 2011. Malaria parasitemia measured through microscopy demonstrated the reverse trend between 2009 and 2011, declining slightly from 32% to 28%; however due to data quality issues in the 2011 survey, the declining trend should be interpreted with caution. Given the different seasons in which the 2009 and 2011 surveys were conducted, it makes it difficult to compare trends across these two surveys; however the RDT data show an overall decline of 21% between 2005 and 2011 (where both surveys were conducted during the rainy season).

Severe anemia among children 6-59 months of age increased from 5% in 2009 to 8% in 2011; similar increases were observed in children 6-23 months of age (7% to 10%) and children 24-59 months of age (4% to 7%). No previous data were available and the surveys were undertaken during different seasons, making it difficult to assess the trend in severe anemia over the evaluation period. Furthermore, other non-malarial factors, such as malnutrition and other infections may have influenced the rise in severe anemia prevalence [139, 140].

The number of confirmed malaria cases reported through the health information system among children under five years of age and people five years of age and above increased gradually from 2009 to 2011, before peaking in 2012, and then declining in 2013. A similar trend was observed in severe malaria cases among children under five years of age, with a steady increase in cases from 2009 to 2012, and then a decline observed in 2013. The rapid expansion of testing of suspected malaria cases and reporting among health facilities makes these trends difficult to interpret. The data suggest a decline in cases occurring between 2012 and 2013, at the end of the evaluation period.

Given the limitations of the data on malaria morbidity, it is difficult to assess trends over the entire evaluation period. However, the data suggest an overall decline in parasitemia prevalence from 2005 to 2011 and a decline in malaria cases toward the end of the evaluation period.

## **Mortality in children under five years of age**

ACCM declined from 109 to 94 deaths per 1,000 live births between 2002–2006 and 2009–2013, though the decline was not statistically significant. In assessing annual mortality trends, it is evident that there was not a consistent decline, but rather ACCM fluctuated over the evaluation period. When looking at mortality by the different age groups, the greatest relative declines between the two survey periods were among postneonates (30%) and infants (25%). Declines were observed in all age groups but child mortality (4q1); however, the decline was only significant among infants. ACCM was greater in rural areas in the 2009–2013 period, and greater relative declines were observed in urban areas compared to rural areas between 2002–2006 and 2009–2013. Altogether, the data suggest a small decline in ACCM over the evaluation period that was mainly due to a decline in infant mortality. Given no significant declines were observed in child mortality however, it is likely too early in the process of expansion of malaria control interventions to have had a

significant impact on ACCM. Much or most of the small decline observed in ACCM, and specifically in infant mortality, was likely due to other contextual factors, which are detailed below.

### **Contextual factors and the plausibility argument**

To examine whether the marked reduction in ACCM could be attributed to the expansion of malaria control interventions, we reviewed other determinants of child survival that could offer alternate explanations for the observed changes in mortality over the evaluation period (summarized in Table 29).

Among the social and economic determinants of child survival, improvements were seen in the overall health system infrastructure, GDP per-capita, national per-capita health expenditure, women's education and literacy, and asset ownership (telephone access), which could have contributed to the declines observed in ACCM between the two survey periods 2002–2006 and 2009–2013. However, the dynamics of socio-economic determinants on population health are often complex [141, 142] and these determinants, arguably [143], operate through the proximate determinants to ultimately affect child survival [77].

During the evaluation period, several proximate determinants changed favoring lower mortality. The coverage of a number of maternal health interventions improved between 2007 and 2013, including ANC attendance (66% to 78%), tetanus toxoid vaccination (75% to 84%), delivery at a health facility (37% to 56%) and with a skilled attendant (46% to 61%). Furthermore, coverage of many child survival interventions demonstrated significant improvements from 2007 to 2013. The percent of children 12-23 months of age that received all recommended vaccinations (BCG, measles, DPT3, and polio) increased significantly from 39% to 55%. Vitamin A supplementation for children 6-59 months of age improved from 42% to 60%. Exclusive breastfeeding rose from 29% to 55%, while the percent of children under five years of age that are stunted (39% to 32%) and underweight (19% to 15%) declined. All these trends suggest improvements in the prevention of childhood illness that are likely to have contributed substantially to the reductions observed in ACCM.

A number of fundamental and proximate determinants remained stable over the evaluation period, including: housing conditions (access to an improved water source, toilet facilities, and floor materials), the percent of women that are married, the percent of births that are high risk or with unavoidable fertility risk; ARI prevalence and care-seeking; diarrhea prevalence, care-seeking and treatment; and HIV prevalence and treatment coverage. Since there were no significant changes in these factors, it is likely that they did not have any influence on the changes observed in ACCM during the evaluation period.

There was only one contextual factor examined that showed a trend that may have influenced ACCM to rise during the evaluation period. The percent of children 6-9 months of age that were breastfed and given complementary foods declined significantly from 62% in 2007 to 42% in 2013.

Overall, Liberia made significant progress in expanding the coverage of many maternal and child health interventions during the evaluation period. This happened alongside the rebuilding of the health care system and infrastructure after the civil war, a steadily rising GDP, and a three-fold increase in national per-capita health expenditure. Thus, the expansion of malaria control interventions occurred in a generally improving environment. It is therefore likely, that the improvements in these contextual factors contributed substantially to the general decline observed in ACCM.

### **Further Analyses**

Multiple logistic regression analyses assessing the association between household ITN ownership with parasitemia prevalence (via RDT) among children 6-59 months of age show a protective effect that was just short of statistical significance. A second similar model examining the association between household ITN ownership by age of the net and parasitemia prevalence showed a significant protective effect on parasitemia for households that owned an ITN for 0 to 6 months. Both models demonstrated that other variables, including age of the child, region of the country, place of residence, malaria risk, and household wealth to be significantly associated with parasitemia prevalence.

## Conclusion

In summary, the findings show that Liberia made progress in expanding coverage of malaria control interventions during the evaluation period, however coverage for all four key interventions remained below the national targets of 80% coverage. Household ITN ownership increased more than three-fold, from 18% in 2005 to 55% by 2013, though household access to an ITN only reached 22% by 2013, demonstrating a gap in sufficient coverage of ITNs. Improvements were also observed in ITN use among the general population, children under five years of age, and pregnant women (32%, 38%, and 37%, respectively by 2013). IRS coverage increased in targeted areas during the latter half of the evaluation period (2009–2012). IPTp coverage had the greatest gains, increasing from 4% in 2005 to just under 50% by 2013. These improvements in IPTp coverage are likely however to have had an influence on neonatal mortality, but minimal impact on ACCM. First-line treatment coverage of children under five years of age also showed significant improvement between 2007 and 2011.

A significant decline was observed in malaria parasitemia prevalence over the evaluation period; RDT results showed a 21% decrease between 2005 and 2011. HMIS data on malaria cases also suggest a decline occurring at the end of the evaluation period. These declines in malaria morbidity are most likely attributable to the expansion of malaria control interventions, given there is no evidence of changes in other factors that would have led to the observed declines. ACCM gradually declined during the evaluation period; however, the decline was mainly due to a significant decrease in infant mortality – from 71 to 54 deaths per 1,000 live births. Child mortality remained stable during this period, which is not consistent with what we would expect had the expansion of malaria control interventions contributed to a reduction

## Estimated Deaths Prevented due to Expansion of Malaria Control Interventions

The expansion of malaria control interventions in Liberia occurred within an overall environment of improvement for maternal and child health. While the evidence does not show a significant impact of the expansion of malaria control on ACCM, it does suggest that alongside other interventions, it contributed to the decline observed in ACCM. We used the Lives Saved Tool (LiST) to estimate the deaths prevented due to the expansion of malaria control interventions. (For more detailed information on the LiST model and the deaths prevented by intervention see Annex 2).

It is estimated that over the period from 2005 to 2013, approximately **4,652** (range: 3,607-5,849) deaths were prevented in children 1-59 months, due to the expansion of ITN household ownership and IRS, compared to what would have happened if no vector control expansion occurred. Under-five mortality is also affected by interventions to control malaria in pregnancy, including ITN use by pregnant women and IPTp during pregnancy. The LiST model estimated that **400** (range: 352-442) deaths in children age 0-59 months were averted due to the expansion of IPTp by pregnant women in Liberia during the evaluation period.

The LiST analysis presented here models the direct effect of malaria interventions on reducing malaria-specific mortality. Given the conservative nature of the LiST model, the estimates presented are likely to be underestimates. **Overall, the LiST model conservatively estimates that the expansion of malaria control interventions during the evaluation period (2005 to 2013) prevented at least 5,052 deaths among children under five years of age in Liberia.**

in ACCM. Due to the trends in ACCM and age-specific child mortality, it was likely too early in the process of expansion of malaria control interventions to have observed a significant impact on ACCM. The evaluation period occurred within an overall environment of improvement in the country post-civil war, where the health care system was being rebuilt, GDP was rising, and other significant improvements in maternal and child health were taking place. Thus, it is likely that these factors contributed to the decrease observed in ACCM, and specifically to the significant decline observed in infant mortality, over the evaluation period.

## REFERENCES

1. National Malaria Control Program and Ministry of Health and Social Welfare [Liberia]. Health Facility Survey Report. Monrovia, Liberia: National Malaria Control Program, Ministry of Health and Social Welfare, 2013.
2. (WHO) WHO. World Malaria Report 2014. Geneva, Switzerland: WHO, 2015.
3. Partnership RBM. The Global Malaria Action Plan for a malaria-free world. 2008.
4. Partnership RBM. Refined/updated GMAP objectives, targets, milestones and priorities beyond 2011. 2011.
5. Rowe AK, Steketee RW, Arnold F, Wardlaw T, Basu S, Bakayita N, et al. Viewpoint: evaluating the impact of malaria control efforts on mortality in sub-Saharan Africa. *Trop Med Int Health*. 2007;12(12):1524-39. Epub 2007/12/14. doi: TMI1961 [pii] 10.1111/j.1365-3156.2007.01961.x. PubMed PMID: 18076561.
6. Victora CG, Black RE, Boerma JT, Bryce J. Measuring impact in the Millennium Development Goal era and beyond: a new approach to large-scale effectiveness evaluations. *Lancet*. 2011;377(9759):85-95. Epub 2010/07/14. doi: 10.1016/S0140-6736(10)60810-0. PubMed PMID: 20619886.
7. Institute for International Programs at the Johns Hopkins Bloomberg School of Public Health and Avenir Health. The Lives Saved Tool (LiST) Baltimore: Johns Hopkins Bloomberg School of Public Health and Avenir Health; 2016 [cited May 2016]. Available from: <http://www.livessavedtool.org/>.
8. Eisele TP, Larsen DA, Walker N, Cibulskis RE, Yukich JO, Zikusooka CM, et al. Estimates of child deaths prevented from malaria prevention scale-up in Africa 2001-2010. *Malar J*. 2012;11(1):93. Epub 2012/03/30. doi: 1475-2875-11-93 [pii] 10.1186/1475-2875-11-93. PubMed PMID: 22455864.
9. Measure Evaluation MD, President's Malaria Initiative, Roll Back Malaria Partnership, UNICEF, and World Health Organization. Household Survey Indicators for Malaria Control. 2013.
10. World Health Organization. WHO policy brief for the implementation of intermittent preventive treatment of malaria in pregnancy using sulfadoxine-pyrimethamine (IPTp-SP). Geneva, Switzerland: WHO Global Malaria Programme, WHO Department of Reproductive Health and Research, WHO Department of Maternal, Newborn, Child and Adolescent Health, 2014.
11. McElroy PD, ter Kuile FO, Lal AA, Bloland PB, Hawley WA, Oloo AJ, et al. Effect of Plasmodium falciparum parasitemia density on hemoglobin concentrations among full-term, normal birth weight children in western Kenya, IV. The Asembo Bay Cohort Project. *Am J Trop Med Hyg*. 2000;62(4):504-12. Epub 2001/02/28. PubMed PMID: 11220768.
12. Snow RW, Omumbo JA, Lowe B, Molyneux CS, Obiero JO, Palmer A, et al. Relation between severe malaria morbidity in children and level of Plasmodium falciparum transmission in Africa. *Lancet*. 1997;349(9066):1650-4. Epub 1997/06/07. doi: 10.1016/s0140-6736(97)02038-2. PubMed PMID: 9186382.
13. Menendez C, Kahigwa E, Hirt R, Vounatsou P, Aponte JJ, Font F, et al. Randomised placebo-controlled trial of iron supplementation and malaria chemoprophylaxis for prevention of severe anaemia and malaria in Tanzanian infants. *Lancet*. 1997;350(9081):844-50. Epub 1997/10/06. doi: 10.1016/s0140-6736(97)04229-3. PubMed PMID: 9310602.
14. Snow RW, Armstrong JR, Forster D, Winstanley MT, Marsh VM, Newton CR, et al. Childhood deaths in Africa: uses and limitations of verbal autopsies. *Lancet*. 1992;340(8815):351-5. Epub 1992/08/08. PubMed PMID: 1353814.

15. Murphy SC, Breman JG. Gaps in the childhood malaria burden in Africa: cerebral malaria, neurological sequelae, anemia, respiratory distress, hypoglycemia, and complications of pregnancy. *Am J Trop Med Hyg.* 2001;64(1-2 Suppl):57-67. Epub 2001/06/27. PubMed PMID: 11425178.
16. National Malaria Control Program and Ministry of Health and Social Welfare [Liberia]. Liberia Malaria Program Review 2014. Monrovia, Liberia: National Malaria Control Program, Ministry of Health and Social Welfare, 2014.
17. Kleinschmidt I, Schwabe C, Benavente L, Torrez M, Ridl FC, Segura JL, et al. Marked increase in child survival after four years of intensive malaria control. *Am J Trop Med Hyg.* 2009;80(6):882-8. Epub 2009/05/30. doi: 80/6/882 [pii]. PubMed PMID: 19478243.
18. Bryce J, Gilroy K, Jones G, Hazel E, Black RE, Victora CG. The Accelerated Child Survival and Development programme in west Africa: a retrospective evaluation. *Lancet.* 2010;375(9714):572-82. Epub 2010/01/15. doi: S0140-6736(09)62060-2 [pii] 10.1016/S0140-6736(09)62060-2. PubMed PMID: 20071020.
19. United Nations Department of Economic and Social Affairs Population Division. 2015 Revision of World Population Prospects Geneva: United Nations; 2015 [cited 2016 April 15]. Available from: <http://esa.un.org/unpd/wpp/>.
20. The World Bank Group. World Development Indicators: Liberia Washington, DC: The World Bank; 2016. Available from: <http://data.worldbank.org/country/liberia>.
21. Liberia Institute of Statistics and Geo-Information Services (LISGIS). 2008 National Population and Housing Census. Monrovia: LISGIS, 2008.
22. Liberia Institute of Statistics and Geo-Information Services (LISGIS) MoHaSWL, National AIDS Control Program [Liberia], and ICF International,, Liberia Demographic and Health Survey 2013. Monrovia, Liberia: LISGIS and ICF International, 2014.
23. Ministry of Health and Social Welfare [Liberia]. National Health Policy and National Health Plan 2007-2011. Monrovia, Liberia: Ministry of Health and Social Welfare, 2007.
24. Ministry of Health and Social Welfare. Liberia Health System Assessment 2015. Monrovia: Ministry of Health and Social Welfare, 2015.
25. Ministry of Health and Social Welfare [Liberia]. National Health and Social Welfare Policy 2011-2021. Monrovia, Liberia: Ministry of Health and Social Welfare, 2011.
26. National Malaria Control Program (NMCP) [Liberia] MoHaSWML, Liberia Institute of Statistics and Geo-Information Services (LISGIS), and ICF International. Liberia Malaria Indicator Survey 2011. Monrovia, Liberia: NMCP, LISGIS, and ICF International, 2012.
27. National Malaria Control Program and Ministry of Health and Social Welfare [Liberia]. National Malaria Strategic Plan 2010-2015. Monrovia, Liberia: National Malaria Control Program, Ministry of Health and Social Welfare, 2010.
28. World Health Organization [WHO]. World Malaria Report 2015. Geneva, Switzerland: WHO, 2015.
29. The Global Fund. Liberia Country Portfolio Geneva, Switzerland: The Global Fund; 2016. Available from: <http://www.theglobalfund.org/en/portfolio/country/?loc=LBR>.
30. Presidents Malaria Initiative (PMI). Liberia Country Portfolio Washington, DC: PMI; 2016 [cited 2016 Mar 21]. Available from: <https://www.pmi.gov/where-we-work/liberia>.
31. National Malaria Control Program and Ministry of Health and Social Welfare. Health Facility Survey Report. Monrovia: National Malaria Control Program, Ministry of Health and Social Welfare, 2009.
32. Gimnig J, Kolczak M, Hightower A, Vulule J, Schoute E, Kamau L. Effect of permethrin-treated bed nets on the spatial distribution of malaria vectors in Western Kenya. *Am J Trop Med Hyg.* 2003;68(90040):115-20.

33. Hawley WA, Phillips-Howard PA, ter Kuile FO, Terlouw DJ, Vulule JM, Ombok M, et al. Community-wide effects of permethrin-treated bed nets on child mortality and malaria morbidity in western Kenya. *Am J Trop Med Hyg.* 2003;68:121 - 7.
34. Howard SC, Omumbo J, Nevill C, Some ES, Donnelly CA, Snow RW. Evidence for a mass community effect of insecticide-treated bednets on the incidence of malaria on the Kenyan coast. *Trans R Soc Trop Med Hyg.* 2000;94(4):357-60. Epub 2000/12/29. PubMed PMID: 11127232.
35. Alonso PL, Lindsay SW, Armstrong Schellenberg JR, Keita K, Gomez P, Shenton FC, et al. A malaria control trial using insecticide-treated bed nets and targeted chemoprophylaxis in a rural area of The Gambia, west Africa. 6. The impact of the interventions on mortality and morbidity from malaria. *Trans R Soc Trop Med Hyg.* 1993;87 Suppl 2:37-44. Epub 1993/06/01. PubMed PMID: 8212109.
36. Lengeler C. Insecticide-treated bed nets and curtains for preventing malaria. *Cochrane Database Syst Rev.* 2004;(2):CD000363. Epub 2004/04/24. doi: 10.1002/14651858.CD000363.pub2. PubMed PMID: 15106149.
37. Snow RW, Molyneux CS, Njeru EK, Omumbo J, Nevill CG, Muniu E, et al. The effects of malaria control on nutritional status in infancy. *Acta Trop.* 1997;65(1):1-10. Epub 1997/04/30. doi: S0001706X96006018 [pii]. PubMed PMID: 9140509.
38. Ter Kuile F, Terlouw D, Kariuki S, Phillips-Howard P, Mirel L, Hawley W, et al. Impact of Permethrin-treated bed nets on malaria, anemia and growth in infants in an area of intense perennial malaria transmission in Western Kenya. *The American Journal of Tropical Medicine and Hygiene.* 2003;68(4 suppl):68-77.
39. Gamble CL, Ekwaru JP, ter Kuile FO. Insecticide-treated nets for preventing malaria in pregnancy [Systematic Review]. *Cochrane Database of Systematic Reviews.* 2009;1:1.
40. Roca-Feltrer A, Carneiro I, Smith L, Schellenberg J, Greenwood B, Schellenberg D. The age patterns of severe malaria syndromes in sub-Saharan Africa across a range of transmission intensities and seasonality settings. *Malaria Journal.* 2010;9(1):282. PubMed PMID: doi:10.1186/1475-2875-9-282.
41. Carneiro I, Roca-Feltrer A, Griffin JT, Smith L, Tanner M, Schellenberg JA, et al. Age-Patterns of Malaria Vary with Severity, Transmission Intensity and Seasonality in Sub-Saharan Africa: A Systematic Review and Pooled Analysis. *PLoS ONE.* 2010;5(2):e8988. doi: 10.1371/journal.pone.0008988.
42. World Health Organization. Guidelines for procuring public health pesticides 2012. Available from: [http://whqlibdoc.who.int/publications/2012/9789241503426\\_eng.pdf](http://whqlibdoc.who.int/publications/2012/9789241503426_eng.pdf).
43. Kim D, Fedak K, Kramer R. Reduction of malaria prevalence by indoor residual spraying: a meta-regression analysis. *Am J Trop Med Hyg.* 2012;87(1):117-24. Epub 2012/07/06. doi: 10.4269/ajtmh.2012.11-0620. PubMed PMID: 22764301; PubMed Central PMCID: PMC3391035.
44. World Health Organization (WHO). World Malaria Report 2009. 2009.
45. World Health Organization (WHO). World Malaria Report 2010. 2010.
46. Abt Associates. Supplemental environmental assessment: Indoor residual spraying for malaria control in Liberia, 2013 - 2018 Bethesda, MD, USA: Indoor Residual Spraying Indefinite Quantity Contract T04: Abt Associates, 2013.
47. Garner P, Gulmezoglu AM. Drugs for preventing malaria in pregnant women. *Cochrane Database Syst Rev.* 2006;(4):CD000169. Epub 2006/10/21. doi: 10.1002/14651858.CD000169.pub2. PubMed PMID: 17054128.
48. Steketee R, Nahlen B, Parise M, Menendez C. The burden of malaria in pregnancy in malaria-endemic areas. *The American Journal of Tropical Medicine and Hygiene.* 2001;64(1 suppl):28-35.

49. Granja AC, Machungo F, Gomes A, Bergström S, Brabin B. Malaria-related maternal mortality in urban Mozambique. *Annals of Tropical Medicine and Parasitology*. 1998;92(3):257-63 %U <http://www.ncbi.nlm.nih.gov/pubmed/9713540>.
50. Guyatt HL, Snow RW. Malaria in pregnancy as an indirect cause of infant mortality in sub-Saharan Africa. *Transactions of the Royal Society of Tropical Medicine and Hygiene*. 2001;95(6):569-76
51. Eisele TP, Larsen DA, Anglewicz PA, Keating J, Yukich J, Bennett A, et al. Malaria prevention in pregnancy, birthweight, and neonatal mortality: a meta-analysis of 32 national cross-sectional datasets in Africa. *The Lancet Infectious Diseases*. 2012;12(12):942-9.
52. Menéndez C, Bardají A, Sigauque B, Sanz S, Aponte JJ, Mabunda S, et al. Malaria Prevention with IPTp during Pregnancy Reduces Neonatal Mortality. *PLoS ONE*. 2010;5(2):e9438. doi: 10.1371/journal.pone.0009438. PubMed PMID: PMC2829080.
53. World Health Organization (WHO). *Guidelines for the Treatment of Malaria*. Second edition. 2010.
54. Ministry of Health and Social Welfare (MOHSW). *Joint Antimalarial Efficacy Study*. 1999.
55. UNICEF. *Mozambique Country Statistics* [cited 2013 October 12]. Available from: [http://www.unicef.org/infobycountry/mozambique\\_statistics.html](http://www.unicef.org/infobycountry/mozambique_statistics.html).
56. Shretta R, Jones, J., Hinneh, D.L., Gilayeneh-Smith, J., Dunah, M., Eghan, K. *Feasibility of Introducing ACTs and RDTs in private sector pharmacies and medicine shops in Montserrado County, Liberia: A qualitative study*. Arlington, VA: National Malaria Control Program, Ministry of Health and Social Welfare and Management Sciences for Health, 2013.
57. *Maternal and Child Health Integrated Program (MCHIP). Strengthening platforms for case management in communities*. Washington DC, USA: MCHIP.
58. *Maternal and Child Health Integrated Program (MCHIP). Review of integrated community case management training and supervision materials in ten African countries*. Washington DC, USA: MCHIP, 2013.
59. Ministry of Health and Social Welfare (MOHSW). *Comprehensive mapping of community health volunteers (CHVS) and community health structures in all health districts of Liberia*. Monrovia, Liberia: MOHSW, 2013.
60. World Health Organization (WHO). *World Malaria Report 2010*. Geneva, Switzerland: WHO, 2010.
61. Ye Y, Kyobutungi C, Louis V, Sauerborn R. Micro-epidemiology of *Plasmodium falciparum* malaria: Is there any difference in transmission risk between neighbouring villages? *Malaria Journal*. 2007;6(1):46. PubMed PMID: doi:10.1186/1475-2875-6-46.
62. Bejon P, Williams TN, Liljander A, Noor AM, Wambua J, Ogada E, et al. Stable and Unstable Malaria Hotspots in Longitudinal Cohort Studies in Kenya. *PLoS Med*. 2010;7(7):e1000304. doi: 10.1371/journal.pmed.1000304.
63. Presidents Malaria Initiative (PMI). *Zambia Malaria Operational Plan (MOP)*. 2010.
64. *Zambian Ministry of Health National Malaria Control Centre. Zambia Malaria Indicator Survey (MIS)*. 2010.
65. Githeko A, Ndegwa W. Predicting malaria epidemics in the Kenyan highlands using climate data: a tool for decision makers. *Global Change & Human Health*. 2001;2(1).
66. *National Malaria Control Program (NMCP) [Liberia] MoHaSWML, Liberia Institute of Statistics and Geo-Information Services (LISGIS), and ICF Macro. Liberia Malaria Indicator Survey 2009*. Monrovia, Liberia: NMCP, LISGIS, and ICF Macro, 2009.
67. Florey L. *Anemia as an Impact Measure of ITN Use among Young Children*. Calverton, MD, USA: ICF International, 2012.
68. Korenromp EL, Armstrong-Schellenberg JRM, Williams BG, Nahlen BL, Snow RW. Impact of malaria control on childhood anaemia in Africa -- a quantitative review. *Tropical Medicine &*

- International Health: TM & IH. 2004;9(10):1050-65 %U <http://www.ncbi.nlm.nih.gov/pubmed/15482397>.
69. Slutsker L, Chitsulo L, Macheso A, Steketee R. Treatment of malaria fever episodes among children in Malawi: results of a KAP survey. *Trop Med Parasitology*. 1994;45(1):61-4.
  70. Biemba G, Dolmans D, Thuma PE, Weiss G, Gordeuk VR. Severe anaemia in Zambian children with *Plasmodium falciparum* malaria. *Tropical Medicine & International Health*. 2000;5(1):9-16. doi: 10.1046/j.1365-3156.2000.00506.x.
  71. Marsh K, Forster D, Waruiru C, Mwangi I, Winstanley M, Marsh V, et al. Indicators of life-threatening malaria in African children. *The New England Journal of Medicine*. 1995;332(21):1399-404 %U <http://www.ncbi.nlm.nih.gov/pubmed/7723795>.
  72. Victora CG, Schellenberg JA, Huicho L, Amaral J, El Arifeen S, Pariyo G, et al. Context matters: interpreting impact findings in child survival evaluations. *Health Policy Plan*. 2005;20 Suppl 1:i18-i31. Epub 2005/11/25. doi: 20/suppl\_1/i18 [pii] 10.1093/heapol/czi050. PubMed PMID: 16306066.
  73. Bryce J, Victora CG, Habicht JP, Vaughan JP, Black RE. The multi-country evaluation of the integrated management of childhood illness strategy: lessons for the evaluation of public health interventions. *Am J Public Health*. 2004;94(3):406-15. Epub 2004/03/05. PubMed PMID: 14998804; PubMed Central PMCID: PMC1448266.
  74. Stratton L, O'Neill MS, Kruk ME, Bell ML. The persistent problem of malaria: addressing the fundamental causes of a global killer. *Soc Sci Med*. 2008;67(5):854-62. Epub 2008/06/28. doi: S0277-9536(08)00234-7 [pii] 10.1016/j.socscimed.2008.05.013. PubMed PMID: 18583009.
  75. Link BG, Phelan JC. Understanding sociodemographic differences in health--the role of fundamental social causes. *Am J Public Health*. 1996;86(4):471-3. Epub 1996/04/01. PubMed PMID: 8604773; PubMed Central PMCID: PMC1380543.
  76. Link BG, Phelan J. Social conditions as fundamental causes of disease. *J Health Soc Behav*. 1995;Spec No:80-94. Epub 1995/01/01. PubMed PMID: 7560851.
  77. Mosley WH, Chen LC. An analytical framework for the study of child survival in developing countries. 1984. *Bull World Health Organ*. 2003;81(2):140-5. Epub 2003/05/22. PubMed PMID: 12756980; PubMed Central PMCID: PMC2572391.
  78. Inhorn M, Brown P. Anthropology of Infectious Diseases. *Annual Reviews of Anthropology*. 1990;19:89-117.
  79. Taylor C, Newman J, Kelly N. The child survival hypothesis. *Population Studies*. 1978;30(2):263-78.
  80. Jones G, Steketee RW, Black RE, Bhutta ZA, Morris SS. How many child deaths can we prevent this year? *Lancet*. 2003;362(9377):65-71. Epub 2003/07/11. doi: S0140-6736(03)13811-1 [pii] 10.1016/S0140-6736(03)13811-1. PubMed PMID: 12853204.
  81. Elsey H. The Contextual Determinants of Malaria.: Casman EA, Dowlatabadi H (eds). Washington, DC: Resources for the Future, 2002, pp. 382. ISBN: 1-891853-19-8. *International Journal of Epidemiology*. 2003;32(3):473-4. doi: 10.1093/ije/dyg168.
  82. Bryce J, Boschi-Pinto C, Shibuya K, Black R. WHO estimates of the causes of death in children. *Lancet*. 2005;365(9465):1147-52.
  83. Rowe AK, Onikpo F, Lama M, Osterholt DM, Deming MS. Impact of a Malaria-Control Project in Benin That Included the Integrated Management of Childhood Illness Strategy. *Am J Public Health*. 2011. Epub 2011/05/14. doi: 10.2105/AJPH.2010.300068. PubMed PMID: 21566036.
  84. Ministry of Health and Social Welfare [Liberia]. Country Situational Analysis Report. Monrovia, Liberia: Ministry of Health and Social Welfare, 2011.
  85. Kruk ME, Rockers PC, Williams EH, Varpilah ST, Macauley R, Saydee G, et al. Availability of essential health services in post-conflict Liberia. *Bull World Health Organ*. 2010;88(7):527-

34. Epub 2010/07/10. doi: 10.2471/blt.09.071068. PubMed PMID: 20616972; PubMed Central PMCID: PMC2897988.
86. Downie R. The road to recovery: Rebuilding Liberia's health system. Washington, DC: Center for Strategic and International Studies, Global Health Policy Center, 2012.
87. Wang L. Determinants of child mortality in LDCs: empirical findings from demographic and health surveys. *Health Policy*. 2003;65(3):277-99. Epub 2003/08/28. doi: S0168851003000393 [pii]. PubMed PMID: 12941495.
88. Boyle MH, Racine Y, Georgiades K, Snelling D, Hong S, Omariba W, et al. The influence of economic development level, household wealth and maternal education on child health in the developing world. *Social Science & Medicine*. 2006;63(8):2242-54. doi: 10.1016/j.socscimed.2006.04.034.
89. Subramanian SV, Belli P, Kawachi I. The macroeconomic determinants of health. *Annu Rev Public Health*. 2002;23:287-302. Epub 2002/03/23. doi: 10.1146/annurev.publhealth.23.100901.140540 100901.140540 [pii]. PubMed PMID: 11910064.
90. Filmer D, Pritchett L. The impact of public spending on health: does money matter? *Soc Sci Med*. 1999;49(10):1309-23. Epub 1999/10/06. doi: S0277953699001501 [pii]. PubMed PMID: 10509822.
91. World Bank. Health expenditure per capita (current US\$) data Washington DC: World Bank; 2016 [cited 2016 August 16]. Available from: <http://data.worldbank.org/indicator/SH.XPD.PCAP>.
92. Government of Liberia and Health Systems 20/20 Project. Liberia National Health Accounts 2007/2008. Bethesda, MD: Health Systems 20/20 project, Abt Associates Inc., 2009.
93. Ministry of Health and Social Welfare TGF, and WHO. Liberia's Health Accounts: July 2011-June 2012. Monrovia, Liberia: Ministry of Health and Social Welfare, 2014.
94. Coleman M, Mabaso ML, Mabuza AM, Kok G, Coetzee M, Durrheim DN. Household and microeconomic factors associated with malaria in Mpumalanga, South Africa. *Trans R Soc Trop Med Hyg*. 2010;104(2):143-7. Epub 2009/09/08. doi: S0035-9203(09)00238-7 [pii] 10.1016/j.trstmh.2009.07.010. PubMed PMID: 19732924.
95. Günther I, Fink G. Water and Sanitation to Reduce Child Mortality: The Impact and Cost of Water and Sanitation Infrastructure. Washington DC: The World Bank, 2011 March 2011. Report No.
96. Gamage-Mendis AC, Carter R, Mendis C, De Zoysa AP, Herath PR, Mendis KN. Clustering of malaria infections within an endemic population: risk of malaria associated with the type of housing construction. *Am J Trop Med Hyg*. 1991;45(1):77-85. Epub 1991/07/01. PubMed PMID: 1867350.
97. Ye Y, Hoshen M, Louis V, Seraphin S, Traore I, Sauerborn R. Housing conditions and *Plasmodium falciparum* infection: protective effect of iron-sheet roofed houses. *Malar J*. 2006;5:8. Epub 2006/02/03. doi: 10.1186/1475-2875-5-8. PubMed PMID: 16451729; PubMed Central PMCID: PMC1373640.
98. Worrall E, Basu S, Hanson K. Is malaria a disease of poverty? A review of the literature. *Trop Med Int Health*. 2005;10(10):1047-59. Epub 2005/09/28. doi: 10.1111/j.1365-3156.2005.01476.x. PubMed PMID: 16185240.
99. Kandji S, Verchot L, Mackensen J. Climate Change and Variability in Southern Africa: Impacts and Adaptation Strategies in the Agricultural Sector: UNEP; 2006. Available from: [http://www.unep.org/themes/freshwater/documents/climate\\_change\\_and\\_variability\\_in\\_the\\_southern\\_africa.pdf](http://www.unep.org/themes/freshwater/documents/climate_change_and_variability_in_the_southern_africa.pdf).
100. The World Bank. Climate Change Knowledge Portal Washington DC, USA: The World Bank; 2016 [cited June 23 2016].

101. The World Bank. World Bank Open Data: The World Bank; 2017 [cited 2017 August 31]. Available from: <https://data.worldbank.org/indicator/AG.LND.PRCP.MM?end=2014&locations=LR&start=1962&view=chart>.
102. International Research Institute (IRI) for Climate and Society. Global Weighted Anomaly Standardized Precipitation Analyses 2012. Available from: [http://iridl.ldeo.columbia.edu/maproom/.Global/.Precipitation/WASP\\_Indices.html](http://iridl.ldeo.columbia.edu/maproom/.Global/.Precipitation/WASP_Indices.html).
103. Gakidou E, Cowling K, Lozano R, Murray CJ. Increased educational attainment and its effect on child mortality in 175 countries between 1970 and 2009: a systematic analysis. *Lancet*. 2010;376(9745):959-74. Epub 2010/09/21. doi: S0140-6736(10)61257-3 [pii] 10.1016/S0140-6736(10)61257-3. PubMed PMID: 20851260.
104. Hobcraft J. Women's education, child welfare and child survival: a review of the evidence. *Health Transit Rev*. 1993;3(2):159-75. Epub 1993/09/05. PubMed PMID: 10146571.
105. Sandiford P, Cassel J, Montenegro M, Sanchez G. The Impact of Women's Literacy on Child Health and its Interaction with Access to Health Services. *Population Studies*. 1995;49(1):5-17. doi: 10.1080/0032472031000148216.
106. Cleland JG, van Ginneken JK. Maternal education and child survival in developing countries: The search for pathways of influence. *Social Science & Medicine*. 1988;27(12):1357-68. doi: 10.1016/0277-9536(88)90201-8.
107. Jejeebhoy S. Women's education, autonomy and reproductive behaviour: experience from developing countries: Oxford: Clarendon Press; 1995.
108. Becker G. Demographic and Economic Change in Developed Countries. Universities—National Bureau Conference Series: Princeton: Princeton University Press; 1960. p. 209–40.
109. CDC. Infant Mortality by Marital Status of Mother -- United States, 1983. Atlanta: Centers for Disease Control and Prevention, 1990.
110. Clark S, Hamplova D. The impact of mother's marital status on child mortality in sub-Saharan Africa: an analysis of birth and marital histories. . Sixth African Population Conference; Ouagadougou, Burkina Faso 2011.
111. Bennett T, Braveman P, Egarter S, Kiely JL. Maternal marital status as a risk factor for infant mortality. *Family Planning Perspectives*. 1994;26(6):252-6+71.
112. The Partnership for Maternal N, and Child Health,.. Opportunities for Africa's newborns: Practical data, policy and programmatic support for newborn care in Africa. 2006.
113. World Health Organization (WHO). Immunization Profile-Malawi 2012. Available from: [http://apps.who.int/immunization\\_monitoring/en/globalsummary/countryprofileresult.cfm?C=mw](http://apps.who.int/immunization_monitoring/en/globalsummary/countryprofileresult.cfm?C=mw).
114. Roper MH, Vandelaer JH, Gasse FL. Maternal and neonatal tetanus. *The Lancet*. 2007;370(9603):1947-59.
115. Michael K, Roy N, McElrath T, Shahidullah M, Wojityniak B. Duration of Protective Immunity Conferred by Maternal Tetanus Toxoid Immunization: Further Evidence from Matlab, Bangladesh. *Am J Public Health*. 1998;88(6):903-7.
116. National Statistics Institute. Final Report of the Multiple Indicator Cluster Survey, 2008. Maputo: National Statistics Institute, 2009.
117. World Bank. Investing in Health. World Development Report. New York: World Bank; 1993 1993/06/30. Report No.: 12183.: 1993.
118. World Health Organization (WHO). State of the World's Vaccines and Immunizations. Geneva: United Nations; 2002.: 2002.
119. Ministry of Health and Social Welfare [Liberia]. National EPI Strategic Plan 2011-2015. Monrovia, Liberia: Ministry of Health and Social Welfare, 2010.
120. World Health Organization (WHO). World Malaria Report 2012. 2012.

121. Bhutta ZA, Ahmed T, Black RE, Cousens S, Dewey K, Giugliani E, et al. What works? Interventions for maternal and child undernutrition and survival. *Lancet*. 2008;371(9610):417-40. Epub 2008/01/22. doi: S0140-6736(07)61693-6 [pii] 10.1016/S0140-6736(07)61693-6. PubMed PMID: 18206226.
122. Bhutta ZA, Labbok M. Scaling up breastfeeding in developing countries. *The Lancet*. 2011;378(9789):378-80.
123. Kramer M, Kakuma R. The optimal duration of exclusive breastfeeding. A systematic review. Geneva, Switzerland: : World Health Organization, 2002 Contract No.: W H O / N H D / 0 1 . 0 8.
124. West J, KP, Caballero B, Black R. Nutrition. In: Merson M, Black R, Mills A, editors. *International Public Health: Diseases, Programs, Systems, and Policies* 1st ed: Aspen Publishers, Inc; 2001.
125. Sommer A, Tarwotjo I, Djunaedi E, West KP, Jr., Loeden AA, Tilden R, et al. Impact of vitamin A supplementation on childhood mortality. A randomised controlled community trial. *Lancet*. 1986;1(8491):1169-73. Epub 1986/05/24. PubMed PMID: 2871418.
126. Beaton GH MR, L'Abbé, et al. Effectiveness of vitamin A supplementation in the control of young child morbidity and mortality in developing countries. 1993.
127. Jamison D, Feachem R, Makgoba M, Bos E, Baingana F, Hofman K, et al. *Disease and Mortality in Sub-Saharan Africa*, 2nd edition Washington (DC): World Bank; 2006.
128. Ahmad O, Lopez A, Inoue M. The decline in child mortality: a reappraisal. *Bulletin of the World Health Organization*. 2000;78:1175-91.
129. Walker N, Hill K, Zhao F. Child Mortality Estimation: Methods Used to Adjust for Bias due to AIDS in Estimating Trends in Under-Five Mortality. *PLoS Med*. 2012;9(8):e1001298. doi: 10.1371/journal.pmed.1001298.
130. African Health Observatory WHO, Regional Office for Africa,, Analytical summary - HIV/AIDS (Liberia): World Health Organization, Regional Office for Africa; [cited 2016 October 4]. Available from: [http://www.aho.afro.who.int/profiles\\_information/index.php/Liberia:Analytical\\_summary\\_-\\_HIV/AIDS#cite\\_note-three-0](http://www.aho.afro.who.int/profiles_information/index.php/Liberia:Analytical_summary_-_HIV/AIDS#cite_note-three-0).
131. Liberia Institute of Statistics and Geo-Information Services (LISGIS) [Liberia] MoHaSWL, National AIDS Control Program [Liberia], and Macro International Inc.,. *Liberia Demographic and Health Survey 2007*. Monrovia, Liberia: Liberia Institute of Statistics and Geo-Information Services (LISGIS) and Macro International Inc., 2008.
132. Liberia Institute of Statistics and Geo-Information Services (LISGIS) [Liberia] MoHaSWL, National AIDS Control Program [Liberia], and ICF International, . *Liberia Demographic and Health Survey 2013*. Monrovia, Liberia: Liberia Institute of Statistics and Geo-Information Services (LISGIS) and ICF International, 2014.
133. National AIDS Commission and National AIDS-STI Control Program [Liberia]. *Global AIDS Response Progress Reporting (GARPR) - 2013: Country Progress Report 2013 Republic of Liberia*. Monrovia, Liberia: National AIDS Commission and National AIDS-STI Control Program [Liberia], 2013.
134. Garcia-Basteiro AL, Schwabe C, Aragon C, Baltazar G, Rehman AM, Matias A, et al. Determinants of bed net use in children under five and household bed net ownership on Bioko Island, Equatorial Guinea. *Malar J*. 2011;10:179. Epub 2011/07/01. doi: 10.1186/1475-2875-10-179. PubMed PMID: 21714859; PubMed Central PMCID: PMC3146899.
135. McElroy B, Wiseman V, Matovu F, Mwengee W. Malaria prevention in north-eastern Tanzania: patterns of expenditure and determinants of demand at the household level. *Malar J*. 2009;8:95. Epub 2009/05/09. doi: 10.1186/1475-2875-8-95. PubMed PMID: 19422704; PubMed Central PMCID: PMC2683859.

136. Noor AM, Omumbo JA, Amin AA, Zurovac D, Snow RW. Wealth, mother's education and physical access as determinants of retail sector net use in rural Kenya. *Malar J.* 2006;5:5. Epub 2006/01/27. doi: 10.1186/1475-2875-5-5. PubMed PMID: 16436216; PubMed Central PMCID: PMC1363723.
137. Macintyre K, Keating J, Sosler S, Kibe L, Mbogo CM, Githeko AK, et al. Examining the determinants of mosquito-avoidance practices in two Kenyan cities. *Malar J.* 2002;1:14. Epub 2002/12/24. PubMed PMID: 12495438; PubMed Central PMCID: PMC149385.
138. Wiseman V, Scott A, McElroy B, Conteh L, Stevens W. Determinants of bed net use in the Gambia: implications for malaria control. *Am J Trop Med Hyg.* 2007;76(5):830-6. Epub 2007/05/10. PubMed PMID: 17488900.
139. Calis JC, Phiri KS, Faragher EB, Brabin BJ, Bates I, Cuevas LE, et al. Severe anemia in Malawian children. *N Engl J Med.* 2008;358(9):888-99. Epub 2008/02/29. doi: 10.1056/NEJMoa072727. PubMed PMID: 18305266.
140. Ngnie-Teta I, Receveur O, Kuate-Defo B. Risk factors for moderate to severe anemia among children in Benin and Mali: insights from a multilevel analysis. *Food and nutrition bulletin.* 2007;28(1):76-89. Epub 2007/08/28. doi: 10.1177/156482650702800109. PubMed PMID: 17718015.
141. Sen A. Mortality as an Indicator of Economic Success and Failure. *The Economic Journal.* 1998;108(446):1-25. doi: 10.1111/1468-0297.00270.
142. Sen A. Health in development. *Bull World Health Organ.* 1999;77(8):619-23. Epub 1999/10/12. PubMed PMID: 10516784; PubMed Central PMCID: PMC2557713.
143. Macassa G, Hallqvist J, Lynch J. Inequalities in child mortality in sub-Saharan Africa: A social epidemiologic framework. *Afr J Health Sci.* 2011;18:14-26.